

**TECHNICAL PUBLICATION
EMA #385**

**Network Design Document
Lake Okeechobee Inflow/Outflow Monitoring Program
(X Project)**

April 2000

by

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EXECUTIVE SUMMARY

The dynamic nature of any comprehensive water quality monitoring network demands that periodic evaluations be conducted to ensure that the system is meeting all its requirements in the most efficient manner possible. A water quality monitoring program with any degree of longevity is prone to hindrances from changes in regulation, operational strategies, methodologies and staff. Over time, the legal and technical goals that define a monitoring system may become unclear and the system may become less efficient due to changing needs. In order to effectively evaluate and optimize a water quality monitoring program, the monitoring objectives and motivations must be clearly defined (Ward 1994). This can be a formidable task when dealing with a monitoring system that has several user groups. The objectives of these groups can differ significantly and a tendency for insulation among user groups can result in a monitoring effort that has been altered to satisfy certain stipulations, but neglects others. This lack of communication can also give rise to "over" monitoring, which is a waste of both valuable man hours and taxpayer's money. A system design document is a useful tool for developing an efficient water quality monitoring program or modifying an existing one.

The South Florida Water Management District (SFWMD or the District) has an extensive water quality monitoring network that covers a variety of aquatic systems, including: estuaries, wetlands, tributaries, rivers and lakes. Some of these projects date back to 1972 and new monitoring projects are constantly being developed as the District's legal obligations, research objectives and management needs are revised. The relationship between water quality monitoring and ecosystem management is likely to play an increasing role in the structuring of sustainability and restoration efforts in this region. For these reasons, it is critical that the documentation of monitoring programs is kept up to date and that longstanding programs are evaluated to ensure efficiency and cost effectiveness.

The purpose of this document is to condense the legal, scientific and managerial aspects of the Lake Okeechobee Inflow/Outflow Monitoring Program (X Project) into a comprehensive reference that includes the historical and current objectives of the project. A clear understanding of these goals is essential in making legal, efficient, and cost-effective decisions regarding any future modifications to this program. The contents of this document are consistent with those outlined in Sanders et. al. (1983). All of the known objectives and information goals of this project are included, and the results of the X Project questionnaire distributed earlier this year were used to identify the information needs of those utilizing the X Project data. A detailed description of the Lake Okeechobee watershed as it relates to X Project monitoring sites is provided in narrative and GIS form. Other pertinent monitoring aspects included are sampling protocols, site descriptions, lab analysis methods, data storage, and data analysis (either detailed or referenced) and data use (as it applies to reporting and managerial decisions). This network design document can be used as a tool to improve the functionality of the X Project by guiding any required changes to the project in the future, and it can also provide a model for documenting other District water quality monitoring programs.

I. INTRODUCTION

A. Watershed Attributes

Lake Okeechobee (26° 58' N, 80° 50' W) is one of the most dominant hydrologic features of the state of Florida and the second largest freshwater body contained solely within the boundaries of the contiguous United States. This large, eutrophic lake has a surface area of 730 square miles, a mean depth of 9 ft. and a maximum storage capacity of 1.05 trillion gallons (SWIM 1993). The lake is at the core of the Kissimmee-Okeechobee-Everglades (KOE) ecosystem, which extends from Lake Kissimmee in the north, central part of the state, to the Everglades and Florida Bay in the south. The lake is surrounded by a 140 mile levy system that is intercepted by a network of channelized canals whose inflows and outflows are entirely controlled (with the exception of Fisheating Creek) by a system of pump stations and spillways. The major structures are either operated by the District or the Army Corps of Engineers (COE). This system allows for the lake's hydrologic regulation and dictates flood control management in the southern portion of the state.

Based on the hydrologic and drainage characteristics of the watershed, the Lake Okeechobee Surface Water Improvement and Management Plan (SWIM)(1989), designated a total of 39 basins as tributary contributors to the lake (Figure 1). Totalling more than 4,600 square miles, this area has base natural coverages consisting of prairies, forested uplands and wetlands. Land use within the watershed is dominated by agricultural interests, with dairy and improved pasture in the north and croplands (sugar cane and vegetable) in the south.

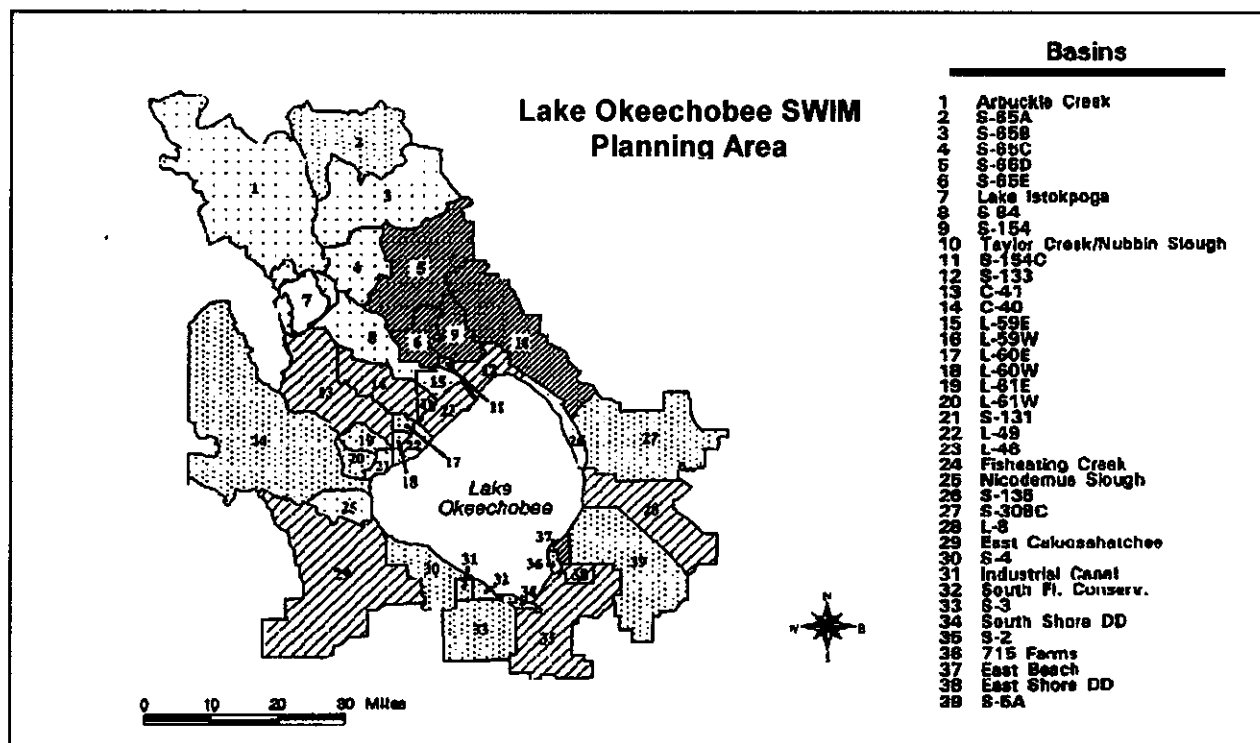


Figure 1. Lake Okeechobee SWIM Plan area basins. (SWIM 1996)

This water body has numerous ecological and human related uses. It is a vital ecological resource for more than a dozen state or federally listed species of flora and fauna and a principal stop-over for migratory birds travelling the Atlantic flyway (SWIM 1989). Lake Okeechobee is a Class I primary drinking water source for 75,000 people, as well as a secondary source for the southeastern coast's estimated population of 4.5 million people (Maceina 1993). Lake Okeechobee also has an economic and cultural connection to the generations of South Floridians who have based their lives around it. It sustains prominent commercial and recreational fisheries and it is essential to the irrigation of crop industries that are of national importance.

B. Project History

Due to the lack of sufficient documentation, staff turnover, and the dynamic nature of this monitoring program, it is difficult to give a 100% accurate account of this project's history. Decisions to alter protocols were made during personal communications or via memorandums that have since been lost. This is a common problem associated with monitoring programs, but the District has taken great strides toward reducing such practices by requiring thorough documentation and tracking monitoring projects on a more frequent basis.

The District began gathering baseline water chemistry data for Lake Okeechobee in 1973 and the study sites located on the perimeter of the lake were registered under the Lake Okeechobee Inflow/Outflow Monitoring Program (X Project). This study preceded the development of management strategies for the lake, but the data collected from 1973-1979 was used to structure the future management and research objectives of the lake. The original project design consisted of 18 sampling stations situated at the major inflows to the lake (Figure 2). The project was expanded to 23 sites by 1979. After completion of construction on all the present water control structures, concerns over major algal blooms in the mid-80's, and the enactment of various legislative measures, the project expanded to its current 35 site design by 1987 (Figure 3). The monitoring network now includes representative sampling stations for all basins on the periphery of the lake.

In terms of total project design, some components are easier than others to trace on a historical basis. Site initialization, as described above, can be traced through the central data base via period of record data. Sampling frequency would ideally be trackable through this same procedure, but data gaps and undocumented policy changes for the X Project have undermined efforts to use this option. Through personal communications with District employees associated with this project, it has been concluded that the sampling frequency regime has changed several times and to compound the confusion, this was not uniform for all sampling stations (B. Jones, L. Grosser et al. 1997). For these reasons, sampling frequency will only be addressed in terms of its current status. The reasons behind different sampling frequency protocols among sites will be discussed as needed. A biweekly flow only and monthly surface water grab sampling routine is followed for all but four sites. These four sites are major contributors to the lake (in terms of flow or nutrients) and are sampled biweekly, regardless of flow.

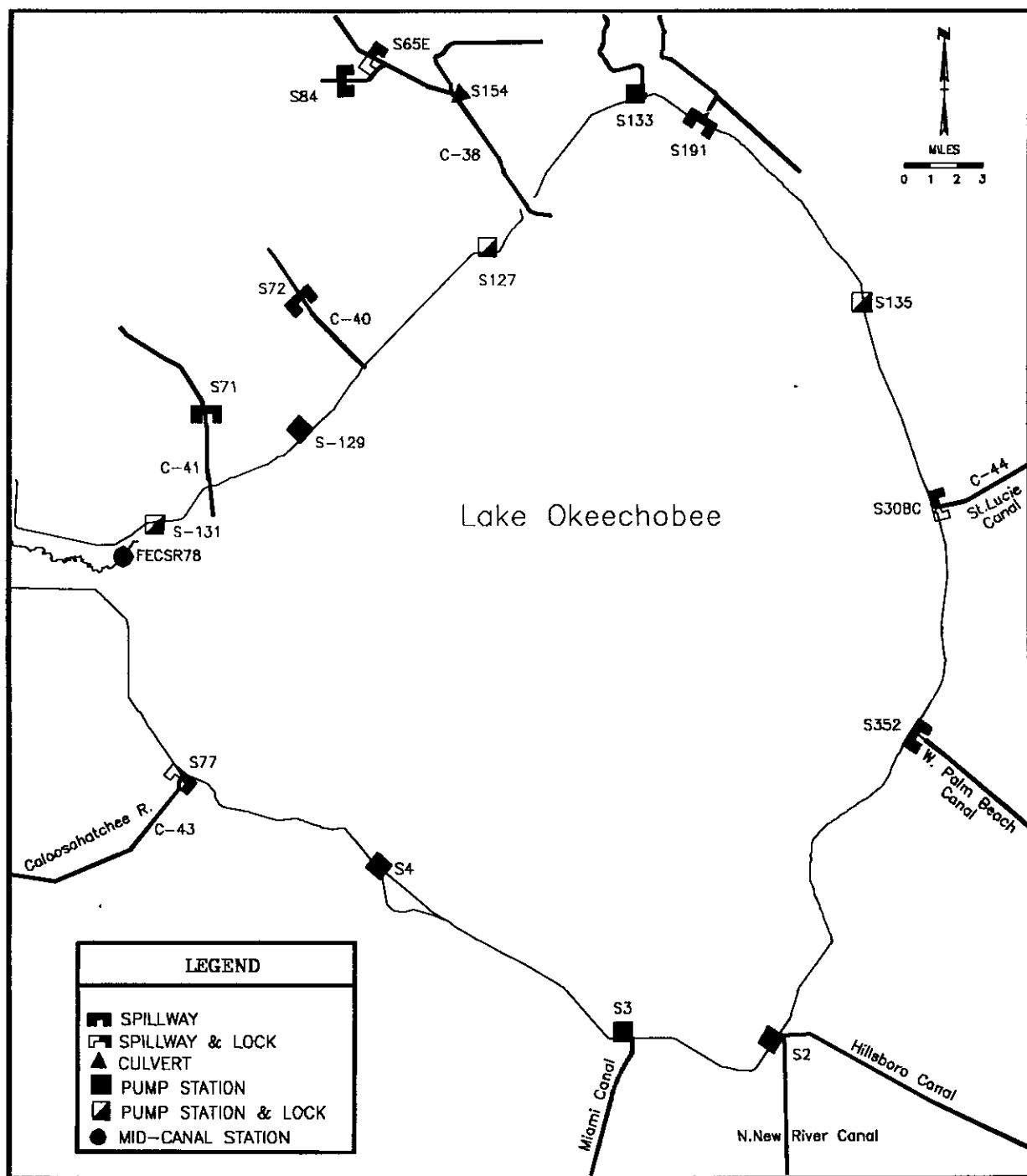


Figure 2. Map depicting the original sampling stations (1973-1979) of the Lake Okeechobee Inflow/Outflow Monitoring Program.

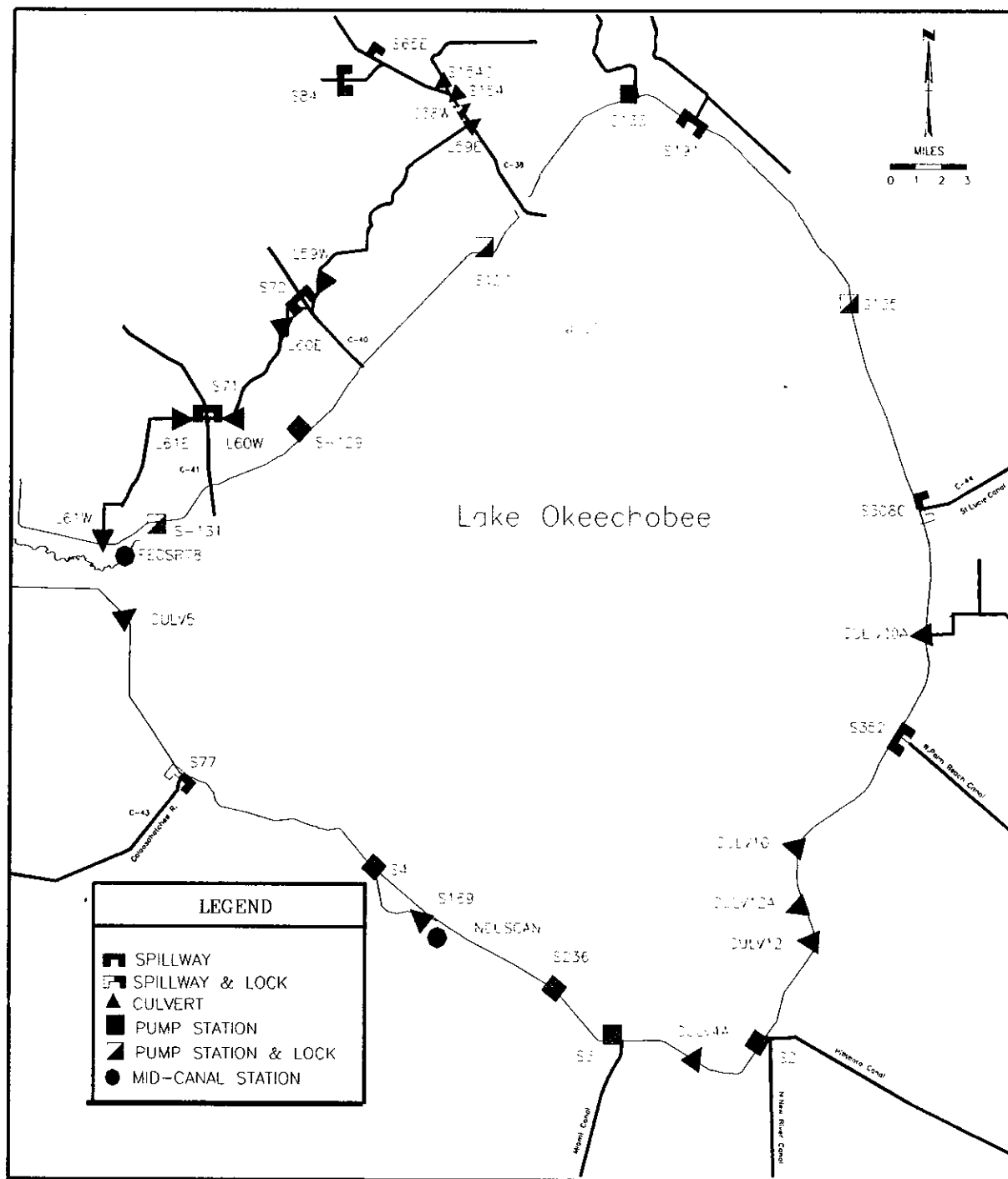


Figure 3. Current sampling station locations of the Lake Okeechobee Inflow/Outflow Monitoring Program (X Project).

Parameter selection has also been a dynamic aspect of the X Project design. The collection of parameters has changed over time and has also differed among sites. A site specific database summary for period of records among physical variables, nutrients, major ions, and trace metals is given in Table 1. The specific parameters currently collected are detailed in the following section of this document.

Table 1. Period of record database summary for variables collected at each of the X Project sampling sites. (updated from CH2M HILL, 1995)

Site	Physical Parameters	Nutrients	Major Ions	Trace Metals
C38W	87 - Present	87 - Present	89 - Present	89 - Present
CULV10	79 - Present	79 - Present	79 - Present	79 - Present
CULV10A	82 - Present	82 - Present	82 - Present	87 - Present
CULV12	79 - Present	79 - Present	79 - Present	79 - Present
CULV12A	79 - Present	79 - Present	79 - Present	79 - Present
CULV4A	79 - Present	79 - Present	79 - Present	79 - Present
CULV5	87 - Present	87 - Present	89 - Present	89 - Present
FECSR78	73 - Present	73 - Present	73 - Present	79 - Present
INDUSCAN	82 - Present	82 - Present	82 - Present	90 - Present
L59E	87 - Present	87 - Present	87 - Present	87 - Present
L59W	87 - Present	87 - Present	87 - Present	87 - Present
L60E	87 - Present	87 - Present	87 - Present	87 - Present
L60W	87 - Present	87 - Present	89 - Present	89 - Present
L61E	87 - Present	87 - Present	89 - Present	89 - Present
L61W	87 - Present	87 - Present	87 - Present	89 - Present
S127	73 - Present	73 - Present	73 - Present	79 - Present
S129	73 - Present	73 - Present	73 - Present	79 - Present
S131	73 - Present	73 - Present	73 - Present	79 - Present
S133	73 - Present	73 - Present	73 - Present	79 - Present
S135	73 - Present	73 - Present	73 - Present	79 - Present
S154	78 - Present	78 - Present	78 - Present	79 - Present
S154C	87 - Present	87 - Present	89 - Present	89 - Present
S169	85 - Present	85 - Present	85 - Present	85 - Present
S191	73 - Present	73 - Present	73 - Present	79 - Present
S2	73 - Present	73 - Present	73 - Present	79 - Present
S236	79 - Present	79 - Present	79 - Present	79 - Present
S3	73 - Present	73 - Present	73 - Present	79 - Present
S308C	73 - Present	73 - Present	73 - Present	84 - Present
S352	73 - Present	73 - Present	73 - Present	79 - Present
S4	76 - Present	76 - Present	76 - Present	79 - Present
S65E	73 - Present	73 - Present	73 - Present	79 - Present
S71	73 - Present	73 - Present	73 - Present	79 - Present
S72	73 - Present	73 - Present	73 - Present	79 - Present
S77	73 - Present	73 - Present	73 - Present	79 - Present
S84	73 - Present	73 - Present	73 - Present	79 - Present

The evolution of this and other monitoring programs associated with the Lake Okeechobee watershed reflects a compliance to numerous legislative actions. There are at least five separate pieces of legislation influencing the X Project (Table 2):

Table 2. Legislation associated with the Lake Okeechobee Inflow/Outflow Monitoring Program.

Legislation	Year Enacted	Status
Lake Okeechobee Operating Permit (LOOP) (#50-0679349)	1979	Updated-1983 / Extension Granted-1989/ Currently in Renewal Stage
Interim Action Plan	1980	Ongoing
Surface Water Improvement and Management Act (LOK SWIM Plan) (Chapter 373.451- 373.4595, F.S.)	1987	Interim Plan (1989) / Updated 1993 / 1997 Update in Circulation
Everglades Agricultural Area Regulatory Program (EAARP) (Chapter 40E-63)	1991	Ongoing / Updated in 1998
Florida Water Quality Standards (Chapter 17-302, F.A.C.)	1993	Ongoing

- 1) The chronology of the legal requirements influencing this monitoring program began in 1979, with the issuance of the temporary Lake Okeechobee Operating Permit (LOOP) by the Florida Department of Environmental Regulation (FDER). This permit was issued in response to citizen pressure for accountability of the quality of water entering the lake. This in turn prompted the development of a more comprehensive monitoring design. Legislative compliance with Surface Water Quality Standards set in Chapter 17-302 of the Florida Administrative Code are intrinsic to the LOOP and project design components (e.g. parameter selection) took this into consideration. The permanent LOOP was approved in 1983, and the provisions of that permit were finalized. The District is currently in the application stage for renewal of the LOOP.
- 2) The Interim Action Plan of 1980 is a District initiative that was developed to prevent excess nutrient inputs (nitrogen and phosphorus) from the Everglades Agricultural Areas (EAA) into Lake Okeechobee. This plan set fixed restrictions on back pumping from the EAA at structures S-2 and S-3. Protocols for water quality monitoring during these occurrences were also established. This plan remains in effect and has not changed from its original draft.

- 3) Under gubernatorial order, the Secretary of the FDER, established the Lake Okeechobee Technical Advisory Committee (LOTAC) in 1985. This group of governmental, agricultural and conservation interests developed reports of their findings and made recommendations on the biological, water quality and water quantity issues for the lake (LOTAC 1986). The Lake Okeechobee Monitoring and Research Plan (1986) was one of the six components presented by LOTAC and it also influenced the design of the X Project.
- 4) The Surface Water Improvement and Management Act (SWIM) of 1987 (Chapter 373.451- 373.4595) was a legislative commitment by the state of Florida to preserve and protect the integrity of its water resources. This act decreed that all Water Management Districts identify their priority water bodies and develop comprehensive management plans for each. The Interim Lake Okeechobee SWIM Plan was drafted in 1989 and Chapter 40E-61 (Works Of The District [WOD]) rules were adopted for the Lake Okeechobee Drainage Basin area. Based on a modified Vollenwieder (1976) model for trophic state assessment (Federico et.al.1981), an annual phosphorus inflow concentration target of 0.18mg/l or below was specified for all lake tributaries. This limit was established in an effort to meet an annually adjusted target loading rate that is derived from model outcomes for each water year (SWIM 1989). At the request of FDER, a total of nine sampling sites were added to the X Project network in 1987.
- 5) The Everglades Agricultural Area Regulatory Program (Chapter 40E-63) of 1992 established a phosphorus load reduction goal of 25% for all discharging basins within the EAA. Three X Project monitoring sites are situated within the boundaries of this watershed definition. The methods outlined in this program called for all future monitoring of these areas to be completed by automatic sampler. The integration of these collection procedures with those currently used for the X Project is pending installation of the automatic samplers and the associated electronics.

The Water Quality Monitoring Division (WQM) is currently responsible for X Project sample collections. From 1979 to 1994 the West Palm Beach field unit performed the project collections. These duties were transferred to the Division's Okeechobee water quality field unit in August of 1994. This transfer allowed collection to be completed in one day by utilizing two sampling teams. Samples are refrigerated overnight (<4°C) and shipped via courier to the SFWMD's Water Quality Monitoring lab the next morning.

II. PROJECT ELEMENTS

The following section details all of the operational components of the Lake Okeechobee Inflow/Outflow Monitoring Program (X Project), and includes sub-sections devoted to site descriptions, field sampling protocols, laboratory analyses, and data management. All of the SFWMD sampling and analytical programs follow the

Comprehensive Quality Assurance Plan #870166G (CQAP) that is approved annually by the FDEP and maintains standards set by the US Environmental Protection Agency (EPA). The SFWMD CQAP details every aspect of quality control as it pertains to surface water ambient monitoring and defines field sampling procedures, chain of custody and quality assurance objectives. Laboratory analytical methods, precision and accuracy targets, and detection limits are also covered in this plan. The most recent updated plan was approved on 11 November 1999 and was distributed as District Technical Publication WRE#383. Those procedures (which are not germane to this report) are referenced according to the section of the CQAP in which they are located.

Note: The monitoring and analytical activities for the X Project are also governed by a project specific quality assurance plan (QAPP #920241P). The QAPP for the X Project differs from the CQAP in that it gives site, variable and data specific information as it pertains to this project. However, it also references the CQAP for most of its procedures.

A. Monitoring Site Descriptions

A1. Station Features

The X Project is an extensive sampling effort that spans over six counties and encompasses all major inflows and outflows currently occurring around the lake. Over 200 miles of vehicle travel are required to complete this fixed station, routine monitoring program. The 35 X Project sampling stations include four different hydrologic types: spillways (8), culverts (16), pump stations (9) and mid-canal stations (2). Four of the sites that are designated as culverts have been equipped to facilitate the pumping of water from fields in the Everglades Agricultural Area (EAA) back into the Lake ("backpumping") for flood control. The specifications and operational criteria for the major SFWMD and COE structures are summarized in Appendix A. These summaries can be used to evaluate flow expectancies under different lake stages and during different seasons. The two mid-canal stations are located on Fisheating Creek (FECRSR78) and the Industrial Canal (INDUSCAN).

A2. Site/Watershed Associations

A total of 34 basins, with a drainage area of 2,542 square miles, represent the hydrologic components of these 35 monitoring sites (Table 3). Agricultural land use is predominant throughout the project region, and in some basins this land use covers nearly 100% of the area (Appendix B). The maps in Appendix B were developed to show land use in relation to specific X Project monitoring sites. This type of information is used in District water quality models to determine water quality trends in relation to basin land use and helps support management and regulatory decisions within the watershed.

Table 3. Drainage areas for the component basins* of Lake Okeechobee Inflow/Outflow monitoring sites.

X Project Site	Component Basins	Acres	Sq. Miles	% Coverage
S-191	TAYLOR CREEK	66,791.84	104	4.1
	NUBBIN SLOUGH	53,471.29	84	3.3
S-133	S-133	25,659.72	40	1.6
S-135	S-135	18,088.36	28	1.1
S-308C	C-44	121,376.9	190	7.5
	BASIN 8	2,303.63	4	0.1
CULV10A	L-8	88,790.45	139	5.5
S-352	S-5A	123,378.40	193	7.6
	PELICAN LAKE DD	752.51	1	0.0
CULV10	EAST BEACH	5,340.00	8	0.3
CULV12A	715 FARMS	3,414.94	5	0.2
CULV12	EAST SHORE	8,415.56	13	0.5
S-2	S-2	106,043.00	166	6.5
CULV4A	SOUTH	2,947.26	5	0.2
S-3	S-3	64,629.11	101	4.0
S-236	S-236	10,622.70	17	0.7
INDUSCAN S-169 S-4	C-21	42,912.43	67	2.6
S-77 CULV5	EAST CALOOSA-HATCHEE	242,995.00	380	14.9
FECSP78	FISH EATING CREEK	282,270.80	441	17.3
L-61W	L-61W	13,567.10	21	0.8
S-131	S-131	7,163.70	11	0.4
S-71	C-41	94,927.87	148	5.8
L-61E	L-61E	14,285.47	22	0.9
L-60W	L-60W	3,270.49	5	0.2
S-129	L-49	12,093.10	19	0.7
S-72	C-40	43,964.34	69	2.7
L-60E	L-60E	5,038.24	8	0.3
L-59W	L-59W	6,439.82	10	0.4
S-127	L-48	20,774.08	32	1.3
S-84	C-41A	58,487.42	91	3.6
L-59E C-38W	L-59E	14,408.48	23	0.9
S-65E	S-65E	29,157.04	46	1.8
S-154C	S-154C	2,178.64	3	0.1
S-154	S-154	31,618.40	49	1.9

B. Sampling Protocols

A general key for surface water grab-sampling of each of the X Project monitoring stations is given in Table 4. This key is used by the scientific technicians and includes exact sampling locations, codes for discharge, notable features affecting the system and other factors that determine which sites to sample and when (i.e. biweekly-mandatory designations and reverse-discharge data availability). Six of the project sites (S154, S191, S2, S3, S65E and S352) are also equipped with automatic samplers. Composite collection is performed once a week at S352 and collection of samples from the S2 and S3 autosamplers only occurs during backpumping events. The collection of daily composites from S191, S154 and S65E is performed on a weekly basis under a different monitoring trip (Lower Kissimmee River).

B1. Frequency/Scheduling

The X Project runs on a biweekly flow-only and monthly sampling routine. Five sites (S154, S84, S71, S191, and S352) are sampled every two weeks, regardless of flow. Grab-samples are collected from S65E on a quarterly basis only, because biweekly sampling of S65E is performed on the Kissimmee River structures (V Project) monitoring trip. A schematic illustrates the specific conditions (flow, no flow and reverse flow) for this type of sampling strategy in Figure 4. The flow-only trip is performed at the beginning of the month and the monthly (regardless of flow) trip is made at the end of the month. This schedule serves to reduce overloading to the lab, and also increases the chances of sampling during periods of flow.

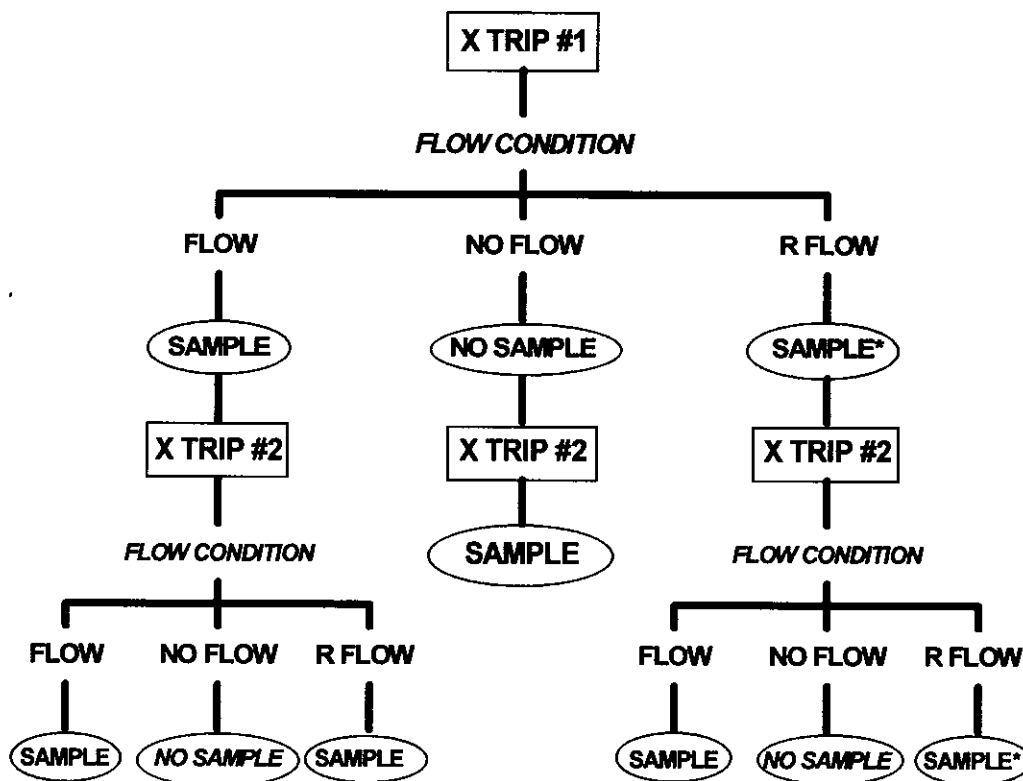


Figure 4. Routine sampling schematic for all non-mandatory X Project sites.

*Applies only to sites with reverse discharge data availability

Table 4. Key to Lake Okeechobee Inflow/Outflow Monitoring Program ("X" Project) sampling sites.

The following sites are sampled on a biweekly (flow-only) and/or monthly basis (regardless of flow). Sites are listed in order of location, beginning at the north central region of the lake and proceeding clockwise around the lake. At sites where there is no reverse-discharge data available, no samples are collected on the flow-only trips if a reverse flow is observed. Notations for all mandatory biweekly sites and sites with reverse-discharge data have been included.

Site	Description	Discharge codes	Notes
S133	A SFWMD operated pump station located on the north side of Lake Okeechobee, immediately west of Taylor Creek and lock S193. Water can be pumped into the lake through S133 or released via gravity. Grab samples are collected from the upstream (north) side of this structure, directly in front of the trash racks.	1 = flow into the lake 2 = no flow 3 = flow from lake	
S191	A spillway gate structure located at the terminus of Nubbin Slough (L67), on the north side of Lake Okeechobee. Water is released into the lake via gravity. Grab water samples are collected on the upstream (east) side of this structure, from the U.S. Highway 98 bridge.	1 = flow into the lake 2 = no flow 3 = flow from lake	⊙ This is A Mandatory Biweekly Site And Samples Are Collected On A Biweekly Basis, Regardless Of Flow. ❖ Daily Composite Autosampler Data Available Under Project LKR.
S135	A SFWMD operated pump station and lock located on the northeast side of Lake Okeechobee. Water is pumped into the lake through S135 or released from the lake via gravity. Grab samples are collected from the upstream (east) side of this structure, directly in front of the trash racks.	1 = flow into the lake 2 = no flow 3 = flow from lake	
S308C	A spillway gate structure located on the east side of Lake Okeechobee at the western terminus of the St. Lucie Canal (C44) in Port Mayaca. Water is primarily released from the lake into C44, but flow from C44 into the lake can also occur during certain stage conditions. Grab samples are collected from the upstream (west/lake side) of this structure.	1 = flow from the lake into C44 2 = no flow 3 = flow into the lake from C44	
CULV10A	A culvert located on the east central side of Lake Okeechobee, at the western terminus of the L8 canal. Water flows via gravity into and from the lake, depending on stage conditions. Grab samples are collected approximately 20 feet upstream (east) of the culvert, from the U.S. Highway 98 bridge.	1 = flow into the lake 2 = no flow 3 = flow from lake	↻ Reverse Discharge Data Available ♦ Upstream land use has contributed to historically high conductivity values at this site.

Table 4. Key to X Project Monitoring Sites Cont.

Site	Description	Discharge codes	Notes
S352	A spillway gate structure operated by the US Army Corps Of Engineers(COE) on the southeast side of Lake Okeechobee. Located at the western terminus of the West Palm Beach Canal at Canal Point, this structure generally releases water out of the lake and into WPB Canal for irrigation and regulatory purposes. However, water can flow into the lake from the WPB Canal during low lake levels. Grab samples are collected on the downstream (east) side of this structure, from the old boat locks in the WPB Canal.	1 = flow from the lake 2 = no flow 3 = flow into the lake	<p>⚡ This is A Mandatory Biweekly Site And Samples Are Collected On A Biweekly Basis, Regardless Of Flow.</p> <p>↔ Upstream/downstream (UD) = 2 (Always)</p> <p>↔ Reverse Discharge Data Available</p> <p>⚡ This site is also equipped with an American Sigma autosampler, located on the southern bank of the upstream side of the structure. This unit is on a flow proportional program and composite samples are collected on a weekly basis. The CR10 data logger must also be "zeroed out" after the samples are collected.</p> <p>* This structure replaced the existing hurricane gate structure (HGSS) in 1989. All samples taken at this site prior to this date are registered in the database as HGSS5.</p>
CULV10	A private pump station on Lake Okeechobee located near the southern limit of Pahokee and operated by the East Beach Water Control District. Water can be pumped into the lake or released from the lake via gravity. Due to access problems, grab samples can be taken from two locations at this station: Grab samples are collected on the upstream (east) side of the pump station at the trash racks, or fifty yards upstream (east) of the pump station from the County Road 715 bridge.	1 = flow into the lake 2 = no flow 3 = flow from lake	<p>* A culvert situated north west of the trash racks contributes discharge from a canal running through Pahokee, along the Herbert Hoover Dike, from the north. If there is a flow coming out of this culvert, the water sample is collected from the area in front of the trash racks.</p> <p>⚡ Upstream land use has contributed to historically high conductivity values at this site.</p>
CULV12A	A private pump station on Lake Okeechobee at Culvert 12A, located about three miles south of Pahokee and operated by 715 Farms Inc. Water can be pumped into the lake or released from the lake via gravity. Grab water samples are collected on the upstream (east) side of the pump station at the trash racks.	1 = flow into the lake 2 = no flow 3 = flow from lake	<p>⚡ Upstream land use has contributed to historically high conductivity values at this site.</p>
CULV12	A private pump station on the southeast side of Lake Okeechobee at Culvert 12, about four miles north of Belle Glade, that is operated by the East Shore Drainage District. Water can be pumped into the lake or released from the lake via gravity. Grab water samples are collected from the upstream (east) side of the pump station at the trash racks.	1 = flow into the lake 2 = no flow 3 = flow from lake	<p>⚡ Upstream land use has contributed to historically high conductivity values at this site.</p>

Table 4. Key to X Project Monitoring Sites Cont.

Site	Description	Discharge codes	Notes
S2	A SFWMMD operated pump station located on the south side of Lake Okeechobee near Belle Glade. It is situated at the confluence of the Hillsboro and North New River Canals and pumps canal water into Lake Okeechobee. The water samples (grab) are collected from the upstream (canal) side of the pump station near the middle of the trash racks.	1 = flow into lake 2 = no flow	↻ Reverse Discharge Data Available ❖ This site is also equipped with an American Sigma autosampler. The intake is located in one of the middle pump bays and flow proportional samples are collected during periods of back-pumping.
S351	Immediately east of S2 is the spillway structure S351 (formerly HGS4). When S351 is releasing water from the lake, a grab sample is collected from the canal side of the structure at the middle spillway. All samples collected at S2 or S351 are recorded as S2 in the database.	3 = flow from the lake through S351	
CUL V4A	A private pump station on Lake Okeechobee, 2 1/2 miles west of Belle Glade that pumps water from the South Shore Drainage District into Lake Okeechobee and release lake water for irrigation. The grab samples are collected from the upstream side of the pump station at the trash racks.	1 = flow into the lake 2 = no flow 3 = flow from lake	♦ Upstream land use has contributed to historically high conductivity values at this site.
S3	A SFWMMD operated pump station located on the south side of Lake Okeechobee at Lake Harbor. Water is pumped from the Miami Canal into Lake Okeechobee. Grab samples are collected on the upstream side of the pump station near the middle of the trash racks.	1 = flow into lake 2 = no flow	↻ Reverse Discharge Data Available ❖ This site is also equipped with an American Sigma autosampler. The intake is located in one of the middle pump bays and flow proportional samples are collected during periods of back-pumping.
S354	Immediately east of S3 is the spillway structure S354 (formerly HGS3). When S354 is releasing water from the lake, a grab sample is collected from the downstream (canal) side of the structure at the middle spillway. All samples collected at S3 or S354 are recorded as S3 in the database.	3 = flow from the lake through S354	
S236	A pump station on Lake Okeechobee between Lake Harbor and Clewiston that is operated by the SFWMMD and South Florida Conservancy District. It pumps water into Lake Okeechobee or releases water from the lake via gravity. Grab water samples are collected from the upstream side of the pump station at the trash racks.	1 = flow into the lake 2 = no flow 3 = flow from the lake	↻ Reverse Discharge Data Available ♦ Upstream land use has contributed to historically high conductivity values at this site.

Table 4. Key to X Project Monitoring Sites Cont.

Site	Description	Discharge codes	Notes
INDUSCAN	A free flowing canal that drains a portion of the agricultural area north of the L1 canal and terminates at the Clewiston Locks (S310) at Lake Okeechobee. Grab water samples from this station are collected from the bridge over the Industrial Canal in Clewiston on County Road 832.	1 = flow towards the lake (north) 2 = no flow 3 = flow from the lake (south)	* This site has no designated upstream or downstream in relation to the lake and the Upstream/downstream (UD) code is left blank. ♦ Upstream land use has contributed to historically high conductivity values at this site.
S169	A spillway gate structure near the boat ramp and the S310 boat locks in Clewiston. This structure permits gravity flow in either direction between S4 and S310 via C20. Grab water samples are collected from the floating walkway ramp, located on the upstream (east) side of the structure.	1 = flow towards S4 (west) 2 = no flow 3 = flow towards S310 (east)	↻ Reverse Discharge Data Available
S4	A SFWMID operated pump station on Lake Okeechobee that pumps water into the lake via C-20. Grab water samples are collected on the upstream side of the pump station near the middle of the trash racks.	1 = flow into the lake 2 = no flow	* This station has limited operations restricted to flood control and hurricane emergencies, so during the dry season, monthly sampling only, can be expected.
S77	A spillway gate structure operated by the COE that is located on Lake Okeechobee at the head of the Caloosahatchee River (C-43). This structure primarily discharges into C-43 for regulatory purposes. Grab samples are collected from the east abutment on the upstream (lake) side of the structure.	1 = flow from the lake into C-43 2 = no flow 3 = flow from C-43 into the lake	↻ Reverse Discharge Data Available
CULV5	A culvert and flap gate located on the west side of Lake Okeechobee on State Road 78, south of Fishheating Creek. Water flows from Nicodemus Slough into Lake Okeechobee and vice versa depending on stage conditions. Grab water samples are collected from the bridge (either side) on State Road 78.	1 = flow into the lake 2 = no flow 3 = flow from the lake	

Table 4. Key to X Project Monitoring Sites Cont.

Site	Description	Discharge codes	Notes
FECSR78	Fishheating Creek is the only naturally free flowing water source that discharges into Lake Okeechobee. Water movement at this location is usually towards Lake Okeechobee or there is no flow. However, during periods of strong easterly winds or high lake levels, lake water can flow into the creek. Grab water samples are collected in the creek from the State Road 78 bridge (either side).	1 = flow into the lake 2 = no flow 3 = flow from the lake	* This site has no designated upstream or downstream in relation to the lake and the UD code is left blank.
L61W	A culvert located at the west end of L61 where it meets the L50 canal at the Herbert Hoover Dike. Water movement at this culvert is by gravity in either direction. Grab water samples are collected from the upstream (north) side of the structure.	1 = flow to the south into Fishheating Creek 2 = no flow 3 = flow to the north into the L61 canal	
S131	A SFWMID operated pump station located on the west side of Lake Okeechobee, between Fishheating Creek and Harney Pond Canal. Water is pumped into the lake through S131 or is released from the lake via gravity. Grab water samples are collected from the upstream side of this structure at the trash racks.	1 = flow into the lake 2 = no flow 3 = flow from the lake	
L61E	A culvert located at the east end of L61, near S71, on the Harney Pond Canal. The water generally flows from L61 into the Harney Pond Canal, immediately below S71. Grab water samples are collected from the upstream (west) side of the culvert.	1 = flow into Harney Pond Canal 2 = no flow 3 = flow from Harney Pond Canal into L61 Canal	
S71	A spillway gate structure located near the northwest side of Lake Okeechobee on Harney Pond Canal (C41) about 1.5 miles north of State Road 78. This structure regulates the gravity fed flows from C41 into Lake Okeechobee. Grab water samples are collected from the upstream (north) side of S71.	1 = gravity flow to the south into Lake Okeechobee 2 = no flow	o This is A Mandatory Biweekly Site And Samples Are Collected On A Biweekly Basis, Regardless Of Flow.
(G207)	A pump station was built by the SFWMID in 1989 to pump water from Lake Okeechobee northward via C41 to the Lake Istokpoga drainage basin. During times of back pumping, samples are taken near the outfall pipe located on the upstream (east) side of S71. Coded as S71 in database.	3 = pumping of lake water north via the C41 canal	

Table 4. Key to X Project Monitoring Sites Cont.

Site	Description	Discharge codes	Notes
L60W	A culvert located at the west end of L60, near S71, on the Harney Pond Canal. The water generally flows from L60 into the Harney Pond Canal, immediately below S71. Grab water samples are collected from the upstream (east) side of the culvert.	1 = flow into Harney Pond Canal 2 = no flow 3 = flow from Harney Pond Canal into L60 Canal	
S129	A SFWMMD operated pump station located on the northwest side of Lake Okeechobee between C41 and Indian Prairie Canal (C40). Water is pumped through S129 into the lake or is released from the lake via gravity. Grab water samples are collected from the upstream (west) side of this structure at the trash racks.	1 = flow into the lake 2 = no flow 3 = flow from the lake	
L60E	A culvert located at the east end of L60, near S72, on the Indian Prairie canal. Water generally flows from the L60 canal into the Indian Prairie Canal, immediately below S72. Grab water samples are collected from the upstream (west) side of the culvert.	1 = flow into Indian Prairie Canal 2 = no flow 3 = flow from Indian Prairie Canal into L60 Canal	
S72	A spillway structure located near the northwest side of Lake Okeechobee, on the Indian Prairie Canal (C40) about two miles northwest of State Road 78. This structure regulates the gravity flows from C40 into Lake Okeechobee. Grab water samples are collected from the upstream (north) side of S72.	1 = gravity flow to the south into Lake Okeechobee 2 = no flow	
(G208)	A pump station was built by the SFWMMD in 1989 to pump water from Lake Okeechobee northward via C40 to the Lake Istokpoga drainage basin. During times of back pumping, samples are taken near the outfall pipe located on the upstream (east) side of S72. Coded as S72 in database.	3 = pumping of lake water north via the C40 canal	
L59W	A culvert located at the west end of L59, near S72, on the Indian Prairie canal. Water generally flows from the L59 canal into the Indian Prairie Canal, immediately below S72. Grab water samples are collected from the upstream (east) side of the culvert.	1 = flow into Indian Prairie Canal 2 = no flow 3 = flow from Indian Prairie into L59 Canal	

Table 4. Key to X Project Monitoring Sites Cont.

Site	Description	Discharge codes	Notes
S127	A SFWMMD operated pump station located on the northwest side of Lake Okeechobee between the Indian Prairie Canal (C40) and the Kissimmee River (C38). Water is pumped through S127 into Lake Okeechobee or is released from the lake via gravity. Grab water samples are collected from the upstream side of this structure at the trash racks	1 = flow into the lake 2 = no flow 3 = flow from the lake	
L59E	A gated structure located at the east end of the L59 canal where it meets the Kissimmee River (C38). Water generally flows from the L59 canal into the Kissimmee River. Grab water samples are collected from the upstream (west) side of the culvert.	1 = flow into Kissimmee River 2 = no flow 3 = flow from the Kissimmee River into L59 Canal	♦ This site has historically high conductivity levels.
C38W	A gated structure located on the west side of the Kissimmee River (C38), three miles south of S65E. Water generally flows into the Kissimmee River. Grab water samples are collected from the upstream (west) side of the structure.	1 = flow into Kissimmee River 2 = no flow 3 = flow from the Kissimmee River	♦ This site has historically high conductivity levels.
S84	A spillway gate structure on C41A, one half mile west of the Kissimmee River (C38). Water flows into the Kissimmee River from C41A, through S84. Grab water samples are collected from the upstream (west) side of this structure.	1 = flow into C38 2 = no flow	○ This Is A Mandatory Biweekly Site And Samples Are Collected On A Biweekly Basis, Regardless Of Flow.
S65E	The southern most spillway and lock structure on the Kissimmee River (C38), located 8.5 miles northwest of Lake Okeechobee. Water is discharged from Pool E of the Kissimmee River into Lake Okeechobee. Grab water samples are collected from the upstream (north) side of the structure.	1 = flow into Lake Okeechobee from C38 2 = no flow	○ This Site Is Sampled Under the X Project for Quarterly Trips Only. (Grab samples are taken on a weekly basis in conjunction with the collection of autosampler data under the V Project) ❖ Daily Composite Autosampler Data Available Under Project LKR.
S154C	A gated structure located on the east side of C38, immediately northwest of S154. Water flows via this culvert into the Kissimmee River (C38). Grab water samples are collected from the upstream side of the structure.	1 = flow into Kissimmee River 2 = no flow 3 = flow from the Kissimmee River	♦ This site has historically high conductivity levels.
S154	A culvert gate type structure located on the east side of the Kissimmee River about four miles south of S65E. This structure allows water to flow from the L62 canal into the Kissimmee River (C38). Grab water samples are collected from the automatic sampler platform, located ~ 150 meters upstream of the structure, on the west side of the canal.	1 = flow into Kissimmee River 2 = no flow 3 = flow from Kissimmee River into L-62 Canal	○ This Is A Mandatory Biweekly Site And Samples Are Collected On A Biweekly Basis, Regardless Of Flow. ❖ Daily Composite Autosampler Data Available Under Project LKR.

B2. Variables

Due to the importance of understanding the dynamics of the lake's system, the X Project has become one of the most intensely sampled projects of the District. A total of 15 physical and chemical variables (parameters) are sampled on a biweekly basis and an additional 14 variables are sampled quarterly (every three months) (Table 5). Variable selection is driven by legislative requirements and the research and management objectives of the SFWMD. Period-of-record ranges for each of the variables are given in Table 6.

Table 5. List and frequency of sampling parameters for the Lake Okeechobee Inflow/Outflow Monitoring Program (X Project).

BIWEEKLY / MONTHLY				QUARTERLY			
TURB	COLOR	NOX	DO	TDS	TOTCD	TOTZN	NA
TSS	OPO4	NH4	PH	SO4	TOTCU	TOTHG	K
TKN	NO2	ALKA	COND	SIO2	TOTFE	CA	
TPO4	CL	TEMP		TOTAS	TOTPB	MG	

B3. Quality Assurance/Quality Control (QA/QC)

All field measures for quality assurance and control are found in Section 6.0 of the CQAP and are uniform for all District surface water sampling projects. This section includes the standards set for the physical collection of samples in the field, the equipment to be used, and the procedures for the decontamination and cleaning of equipment. This section also depicts the QA/QC elements for autosamplers. Section 7.0 of the CQAP provides details on the methods for sample custody, which consists of field sample documentation, transport, transmittal, tracking, storage, rejection and security. The required field QC samples are given in Section 11.0 of the CQAP.

C. Laboratory Analyses

All samples collected on the X Project are analyzed at the SFWMD Laboratory located at 1480-9 Skees Road in West Palm Beach, FL. However, during times of overload to the laboratory, parameters with shorter holding times may be sent to a contract lab for analysis. The X Project contributes about 4.5% of the overall yearly load to the SFWMD lab, with a range of 7,394 to 11,684 resulting analyses. The laboratory's analytical procedures for all surface water samples follow those guidelines found in Section 8.0 of the CQAP. The quality assurance and control measures followed by the lab are found in Section 11.0 of the CQAP.

Table 6. Period of record descriptive statistics for variables collected at all Lake Okeechobee Inflow /Outflow Monitoring Program sampling stations.

	TEMP °C	DO mg/L	COND uS/cm	PH pH unit		SIO2 mg/L	SO4 mg/L	TOTAS ug/L	TOTCD ug/L
# of Values	9136	9043	8973	9418	# of Values	2246	2956	1531	1503
MIN	9.5	0.1	2	4.8	MIN	<1	<1	<1.5	<0.3
MAX	37.7	16	14680	10.2	MAX	82.4	960.4	27	39.6
MEDIAN	21.9	5.2	518	7.2	MEDIAN	17.7	177	1.2	0.1

	TURB ntu	COLOR Pt-Co unit	TSS mg/L	TDS mg/L		TOTFEii ug/L	TOTCU ug/L	TOTPB ug/L	TOTZN ug/L
# of Values	8885	8634	8494	597	# of Values	565	1532	1505	1525
MIN	<0.1	<1	<1	36	MIN	15.7	<1.2	<0.8	<4
MAX	497	9892	987	5910	MAX	3270	15.9	8.05	857
MEDIAN	1.1	101	1	303	MEDIAN	1	1.2	0.05	0.1

	NOX mg/L	NH4 mg/L	CL mg/L	ALKA mg/L		NA mg/L	K mg/L	CA mg/L	MG mg/L
# of Values	9909	9836	9967	2578	# of Values	3211	2741	3224	3219
MIN	<0.004	<0.01	<0.5	1.6	MIN	1.3	0.2	3.37	1.15
MAX	21.405	4.99	4313.1	5021	MAX	2880	74.8	318	191
MEDIAN	0.01	0.08	1.1	1.7	MEDIAN	1.9	0.3	0.1	0.1

	NO2 mg/L	TKN mg/L	OPO4 mg/L	TP mg/L		TOTHG ug/L
# of Values	9962	9953	9747	9919	# of Values	1530
MIN	<0.004	<0.5	<0.004	<0.004	MIN	<0.2
MAX	1	11.93	2.34	2.59	MAX	1.1
MEDIAN	0.004	0.72	0.007	0.077	MEDIAN	0.05

* This table does not take into account the variation in flow volumes among the monitoring sites and is given only as a descriptive summary of historical data collected from all sites around the lake. Concentrations do not represent mean contributions distributed evenly for all inflows because many sites constitute very minor inflows to the lake.

D. Data Management / Review

There is a specified path (from field to archival) that all data gathered under the X Project must follow. The flow of data is connected to a series of checks to assure that quality objectives are being met and the integrity of the data is being upheld. Numerous individuals are responsible for maintaining the data management goals of this project. A general account of the District's methods of data validation, review, reporting and storage is detailed in Section 12.0 of the CQAP. Data review template sheets with site specific period-of-record averages for all variables sampled under the X Project have been developed to aid in the review process at the project manager level (Table 7).

Table 7. Example of X Project template sheet for review of preliminary data.

S154		S154 Quarterly	
POR AVG. PRODUCT		POR AVG. PRODUCT	
11.73	ALKA	11.73	ALKA
	APA		APA
	CA	20.91	CA
	CARO		CARO
	CHLA		CHLA
	CHLA 2		CHLA 2
	CHLB		CHLB
	CHLC	12.73	CHLC
11.73	CL		CL
	COD	11.73	COD
21.27	COLOR	21.27	COLOR
	DCR6		DCR6
	DIC		DIC
	DOC		DOC
	F		F
	K	5.97	K
	LCOND		LCOND
	LPH		LPH
	LTSS		LTSS
	M G	11.01	M G
	NA	45.73	NA
0.00	NH4	0.00	NH4
	NOB		NOB
0.010	NO2	0.010	NO2
0.043	NOX	0.043	NOX
0.272	OP01	0.272	OP01
	PHEO		PHEO
	SIO 2	1.11	SIO 2
	SO4	3.15	SO4
	TDKN		TDKN
	TDPO4		TDPO4
	TDS	24.77	TDS
	TDSAG		TDSAG
	TDSAL		TDSAL
	TDSAS		TDSAS
	TDSBA		TDSBA
	TDSBE		TDSBE
	TDSCD		TDSCD
	TDSCR		TDSCR
	TDSCU		TDSCU
	TDSDE		TDSDE
	TDSHG		TDSHG
	TDSMN		TDSMN
	TDSNI		TDSNI
	TDSPB		TDSPB
	TDSSB		TDSSB
	TDSSE		TDSSE
	TDSSN		TDSSN
	TDSSR		TDSSR
	TDSTL		TDSTL
	TDSZN		TDSZN
	TIC		TIC
11.01	TKN	11.01	TKN
	TOC		TOC
	TOTAG		TOTAG
	TOTAL		TOTAL
	TOTAS	11.751	TOTAS
	TOTBA		TOTBA
	TOTBE		TOTBE
	TOTCD	0.959	TOTCD
	TOTCR		TOTCR
	TOTCU	1.732	TOTCU
	TOTFE	1.015	TOTFE
	TOTHG	0.121	TOTHG
	TOTMN		TOTMN
	TOTNI		TOTNI
	TOTPB	1.512	TOTPB
	TOTSB		TOTSB
	TOTSE		TOTSE
	TOTSN		TOTSN
	TOTZN	7.110	TOTZN
	TOTTL		TOTTL
0.026	TP04	0.026	TP04
0.0	TSS	0.0	TSS
0.0	TURB	0.0	TURB
	VSS		VSS

III. PROJECT OBJECTIVES

Water quality monitoring programs must be designed to supply high quality data that can provide useful and timely information about the water body of concern and its associated watershed. This information can be used in concert with results from experimental and process-oriented research and can be incorporated into modelling efforts to generate scientifically sound methods to preserve and enhance the area's water quality condition. Thus, the elements necessary to construct an effective pathway from data collection to information dissemination are crucial to the success of a monitoring project. The operational portion of this process, described in the previous section, represents the functional efforts required for a successful monitoring project. The informational component of a monitoring effort constitutes the remaining elements for completing the data collection to dissemination link. These elements include information goals, statistical analysis of data, information presentation, and incorporation of information into management initiatives.

A. Information Goals

Defining the monitoring goals and anticipated uses of a project provides an essential link between effective data collection and data access. This step provides a foundation for the project's design and implementation and serves as the nucleus from which all the other project elements should originate. Unfortunately, this fundamental aspect is often under emphasized in the developmental stages of a monitoring project. Although there is no record of such a defining document for the X Project, there is a summary of the project's scope and purposes that was compiled in the SFWMD Surface Water Quality Monitoring Network Technical Memorandum (Germain 1988).

The information needs associated with the X Project are numerous and vary with respect to their ultimate function. This diverse set of objectives can be roughly divided into two sub-groups consisting of legal requirements (i.e. mandated monitoring) and administrative directives (e.g. management implications, research objectives and public interests). Many of the following objectives are derived from Germain 1994, but the questionnaire distributed to data users has helped to augment this list.

A1. Legal Requirements

The X Project's design supports the regulatory functions of the District and the State of Florida by fulfilling monitoring requirements that:

- ◆ Supply definitive water quality data to the Florida Department of Environmental Protection, as mandated by the monitoring requirements of the 1983 *Lake Okeechobee Operating Permit* (#50-0679349):
 - ◆ Evaluation of data for compliance to Class I and III water quality standards (Chapter 17-302, F.A.C.) is part of the operating permit's data review process;
- ◆ Fulfill the recommendation of the *Lake Okeechobee Technical Advisory Committee (LOTAC)* to establish a comprehensive monitoring program as defined in the Lake Okeechobee Monitoring and Research Plan (FDER 1986);

- ◆ Allow for measurements of the effectiveness of basin management plans to reduce the nutrient load to the lake and to assess compliance with phosphorus concentration limits for tributary inflows as required by the *Surface Water Improvement and Management Act of 1987 (SWIM)* (Chapter 373.451-373.4595, F.S.);
 - ◆ Historical load calculation stations used by Federico et. al, 1981 must be maintained in order to support the calculation of the regulated load.
- ◆ Uphold the protocols for water quality sampling during back pumping events, at structures S2 and S3, as directed in the *Interim Action Plan of 1980*;
- ◆ Provide nutrient concentration data from S351(S2), S352 and S354(S3) for the *Everglades Agricultural Area Regulatory Program of 1992* (Chapter 40E-63).

The site specific requirements of these legislative measures are given in Table 8.

A2. Administrative Objectives

The X Project was originally established to provide a water quality database to measure the chemical loadings from discharges of major inflows to and outflows from the lake. Over the last two decades, this program has emerged as a pivotal source of information that is vital to lake research initiatives and supplies data that are utilized to uphold District directives concerning Lake Okeechobee. These include:

- ◆ Development of water quality management strategies for the watershed;
- ◆ Calculation of the phosphorus "load to the lake" model;
- ◆ Trend detection of potential water quality problems;
- ◆ Establishment of nutrient budgets for Lake Okeechobee;
- ◆ Validation and development of water quality models;
- ◆ Information dissemination to the regulated communities and to public inquiries on basin water quality.
- ◆ Lake Okeechobee status and trend assessment;
- ◆ Evaluating the Kissimmee River Restoration Project's efforts to improve discharges to the lake;
- ◆ Ancillary information for in-lake ecological studies;
- ◆ Evaluating any impacts from basin land use changes;
- ◆ Measuring water quality effects on receiving estuarine systems.

Table 8. Site specific requirements of legislative acts influencing the X Project.

SITE	LOOP	SWIM Plan	Interim Action Plan	EAARP
S133	X	X		
S191	X	X		
S135	X	X		
S308C		X		
CULV10A		X		
S352		X		X
CULV10		X		
CULV12A		X		
CULV12		X		
S2	X	X	X	
S351				X
CULV4A		X		
S3	X	X	X	
S354				X
S236		X		
INDUSCAN		X		
S169				
S4	X	X		
S77		X		
CULV5		X		
FEC SR78	X	X		
S131	X	X		
L61W		X		
L61E		X		
L60W		X		
S71	X	X		
S129	X	X		
L60E		X		
L59W		X		
S72	X	X		
S127	X	X		
L59E		X		
C38W				
S154	X	X		
S154C		X		
S65E	X	X		
S84	X	X		

B. Statistical Strategies

An integral part of water quality monitoring design is the identification of the statistical methods to be employed. A monitoring project's statistical design criteria should be selected to test the hypotheses derived from the overall monitoring goals and objectives (Sanders, et. al. 1994). Most analyses associated with water quality variables involve trend detection using non-parametric tests and linear or multivariate regressions. Since X Project data are used for a diverse set of objectives and analyzed in various ways by numerous groups, the concept of administering one basic statistical approach is not realistic. However, for a significant portion of the data analyses, the project data is tested for annual linear trend detection.

The primary focus of the X Project's design is the estimation of long-term phosphorus loading (i.e. annually) to Lake Okeechobee and the identification of trends in total phosphorus and other water quality variables over time. The manner in which regulatory programs were developed for this watershed has dictated an orientation toward sampling activities designed to obtain average concentrations, but it is the "integral of instantaneous loading over time" that is this project's main interest (Lettenmaier and Wilson 1992). A time-weighted average interpolation method is used to determine daily mean concentrations from periodic sample data, which are then multiplied by gauged discharges to compute a daily load (Gain 1997). A log-log linear regression of load on flow is calculated to obtain quarterly, yearly and five year rolling averages of load, which are then compared to the adjusted modified-Vollenweider target load. The District's load calculation program is written in FORTRAN and is run on a quarterly basis. This program produces three graphs that pertain to Lake Okeechobee phosphorus inputs and trends (Wang 1996).

Historical X Project data have been analyzed for linear regressions, trends in concentrations over time, seasonal and temporal distributions, and hypothesis tests of variances between nutrient loading for pre and post basin-wide management plan implementations. These analyses are prominent in the literature of this watershed, and have been performed on an as-needed, user specific basis.

C. Reporting Techniques

The manner in which data are presented is also crucial to the success of a monitoring program. Since X Project data are used by several interest groups, the information must be presented in a manner that can be understood by both professional and lay audiences. A proper format for presentation of the information obtained from monitoring programs must be established in order to ensure the information is being disseminated to the users in an effective manner. Although a balance between scientific presentation and public education can be difficult to achieve, the District has managed to accomplish this task through diverse reporting strategies. The information obtained from X Project data is regularly incorporated into District publications and scientific papers that vary greatly in their content and structure. These range from monthly, station specific information sheets, to multifaceted federal, state and District reports (Table 9).

Table 9. Descriptive list of periodic reports that utilize X Project data.

REPORT NAME	FREQUENCY OF DISTRIBUTION	DESCRIPTION
<i>Okeechobee Water Quality Monitoring Program: Data Summary Report</i>	Monthly	A SFWMD report that lists the monthly total phosphorus (TP) concentration data for all the LOK tributary and inflow/outflow monitoring stations sampled in specific areas of the watershed. This report is distributed internally and to FDEP, NRCS, DACS and interested members of the public.
<i>Water Quality Conditions Quarterly Report</i>	Every Three Months	A SFWMD publication presented to the Governing Board and public, that details the water quality conditions of major water bodies within the District. This report incorporates X Project data, as it relates to the lake load calculation and basin specific flow weighted TP concentrations for S154, Kissimmee River, Taylor Creek/Nubbins Slough and Fisheating Creek.
<i>Lake Okeechobee Water Quality Report</i>	Annually	A SFWMD report prepared for FDEP in fulfillment of the LOOP requirements. This report currently consists of a yearly listing of all X Project raw data, along with the pesticides monitoring program data and an account of back pumping activities at S2 and S3 for the previous year.
<i>Water Quality Assessment for the State of Florida [305(b) Report]</i>	Annually	A FDEP publication that indexes the quality and trends of Florida's surface waters. FDEP analyzes the yearly data of 12 water quality variables that have been submitted by state and local agencies to the EPA's STORET database. A Spearman's Ranked Correlation for trends of annual averages determines whether the state water bodies are meeting their designated uses and assigns a classification of worse, better or no trend for these areas.
<i>Lake Okeechobee Surface Water Improvement and Management Plan (SWIM)</i>	Updated Every Four Years	A comprehensive management plan developed by the SFWMD that details the progress of load reduction strategies and other water quality issues concerning LOK (e.g. Class I/III Water Quality Standards, Best Management Plan assessments and Works of the District status). Information from the X Project is significant to the formulation and scope of these plans.

IV. DISCUSSION

The X Project has a period of record dating from 1973. The enactment of legislative requirements and the dynamic nature of research oriented management strategies have prompted significant expansions to this monitoring program's design and scope. Advances in the technological methodologies (modeling, hydrologic data acquisition, etc.) used to fulfill these legal and research objectives have also affected the X Project's design. The progression of District approaches to addressing environmental concerns of governmental agencies and the public has augmented the degree to which these data are used and diverse applications of this data set have been established. Maintaining this level of versatility and efficiency over many years can only be accomplished through close management and scrutiny. Projects of this nature must be thoroughly documented and periodically reviewed. Mechanisms that enable feedback from end users must be in place and a commitment to explore potentials for improvement, in all aspects of the project's design, must be assumed.

Reorganizations within the District have also had an effect on the way water quality monitoring projects function and how they are managed. For certain projects, an atmosphere of isolation between data collection and data use can occur. The problems associated with this insular style of project management are chronic and may not always be immediately evident. The effectiveness of projects that are not closely administered at both the field and research level can deteriorate inconspicuously. Changes in staff and project ownership may allow for discrepancies or inconsistencies in sampling protocols to go unnoticed for long periods of time. Data review procedures may become less thorough with priority changes in research objectives and work load, and revisions to the informational goals and objectives of end users can fail to be reflected in the project's design.

This design document was developed to provide the information necessary to resolve any discovered inconsistencies and prevent these types of problems from occurring in the future. The following sections represent an effort to review the project with these goals in mind: A feedback mechanism in the form of a questionnaire was developed and distributed to all X Project data users; the potential for improved monitoring were investigated by revisiting past statistical reviews of project design; the implications of the pending renewal of the LOOP were addressed; and recommendations for improved monitoring, management and review were developed.

A. Questionnaire Results

Due to the numerous demands placed on this data set, a cooperative effort among District staff members was required to gather the information contained in this document. An X Project questionnaire was developed and distributed to all potential end users. A total of 20 questionnaires were distributed to those on the staff who expressed an interest in participating in the survey. A total of 10 were returned completed. The questionnaire and a compilation of all the corresponding replies is given in Appendix C. Although the level of response was lower than hoped for, this survey proved to be an effective method for identifying the information needs of those using X Project data.

The responses indicated that most of the research data requirements are being met with the least amount of sampling possible and that the data from the X Project supplies an adequate field from which to generate information about the water quality trends of this watershed. Even though the current project design seems to be addressing all of the research and management objectives at an acceptable level, the demand for event driven (high rainfall-peak flow) sampling was suggested by several users and requests for specific variable frequency changes (i.e. quarterly to monthly) were also stated. Suggestions for possible reductions in sampling were solicited, but most end users did not feel that site eliminations or reducing sampling frequency would be legally or scientifically feasible at this time.

B. Review of Design Optimization Efforts

The calculation of phosphorus loading to the lake is a primary objective of this data set and the X Project's design should accommodate this function in the most effective manner possible. Efforts to fulfill this need have come in the form of two independent statistical reviews that evaluated the effectiveness of the X Project's design, as it relates to load calculation and trend detection.

The *Lake Okeechobee Water Quality Monitoring Program Review* was conducted by Lettenmaier and Wilson in 1992. Although this review encompassed all of the current monitoring activities (Dairy, Works of the District and the X Project) that track the conveyance of phosphorus to the lake, only the information relevant to the X Project will be addressed here. The design optimization network offered by Lettenmaier was developed through the completion of the following technical objectives (taken from Lettenmaier and Wilson 1992):

- Minimize the variance of the estimate of the phosphorus load (discharge-weighted concentration) entering the lake.
- Maximize the power for detection of trends in concentrations of phosphorus entering the lake.

This review focused on data from the 19 control structure stations that had both total phosphorus and discharge records available (POR to 1991). Lettenmaier applied a modified rating curve methodology to estimate a log load – log flow regression for each of the 19 stations. Sampling strategies were derived by examination of the discharge-concentration relationship and the contribution of each of the stations to the total lake phosphorus load. Although the current District method for calculating load considers only inflow, Lettenmaier also included stations with reverse discharges or outflow from the lake (S308C, S77 and INDUSCAN), in order to assess the best method for determining a lake phosphorus budget. Prioritization (primary and secondary) of each of the 19 stations was based on the contribution of each to the total phosphorus budget.

This optimized network was developed for load error reduction and trend estimation, with a resulting sampling strategy that balanced both. The recommendations of this review centered around the development of revised sampling frequencies for the 19

stations examined, but also involved the cost benefit of eliminating sites that were not contributing significantly to the total load. Since the elimination of a majority of the current sampling stations is not a legal or research feasible option, the optimized network proposed by Lettenmaier could only be implemented in terms of sampling frequency revisions. In some cases, the recommended frequency of secondary stations was lower than that currently sampled (monthly versus semimonthly). Monthly sampling at many of the current X Project stations is required under the SWIM Plan or the LOOP and these reductions could not be executed. Increased sampling frequencies (monthly to biweekly) for the primary stations are already achieved under the current sampling design, with the exception of stations S308C, S4 and INDUSCAN. The S308C station is a primary outflow and although it is not figured into the current load calculation model, data from this site is used to calculate yearly nutrient budgets for the lake. The benefits of increased monitoring at this site would need to be evaluated further by an internal review. Recent discharge and concentration data for the S4 station would need to be re-examined using a more current date set. An internal review would also be required to determine if additional sampling would be warranted. The INDUSCAN station is not a primary inflow, and Lettenmaier's recommendation of increased sampling was based on the significance of a data set with a large number of reverse flows (away from the lake). The hydrology of this site and the sampling location relative to the S310 lock structure and S169 would need to be investigated before this additional sampling could be justified.

The second review, *An Optimized Network for Phosphorus Load Monitoring for Lake Okeechobee, Florida*, was recently released by W. Scott Gain of USGS. This proposed optimized network was developed to minimize the random and systematic errors in total load estimates for a certain level of monetary investment (Gain, 1997). The optimization process involved the following operations (taken from Gain, 1997):

- An evaluation of the explained and unexplained variations in daily mean loading rates based on available data (1982-1991);
- The computation of uncertainty estimates for each of several monitoring alternatives; and
- The selection of the most cost-effective combination of monitoring alternatives to produce the greatest overall decrease in uncertainty for the least increase in expense.

Gain examined 48 distinct sources of direct discharge into or away from the lake. Of those, he found that 17 stations contributed a significant amount of the variance in load. This review addressed the contribution of concentration and discharge data to the total load error. The sampling alternatives for discharge monitoring (Q0,Q1,Q2) and concentration monitoring (C0,C1,C2,C3) were developed by determination of those sites at which additional sampling, in the form of trained observers and instrumentation (autosamplers and acoustic-velocity measuring devices), would result in the greatest reduction of total load error. The water quality component called for additional sampling (from the baseline of two samples per year) at each of the 17 significant stations. For the C3 alternative, Gain recommended that 11 stations be equipped with autosamplers. Under the C2 alternative, 5 stations would be sampled routinely by

trained observers and 1 additional site must be sampled at least 12 times per year under the C1 alternative. Implementation of these sampling alternatives would reduce the error in load calculation by 20tons/year or ~4% of the absolute load. The total error reduction (concentration plus discharge) was estimated to cost \$200,000 in 1992 dollars.

A review of the optimum network alternatives reveals that many of the recommendations suggested by Gain are already in place under the current sampling design and in many cases exceed the recommended sampling. The C1 alternatives to sample the Culvert 10A station 12 times per year presently occurs and the C2 alternative that calls for additional sampling (25+ times per year) at stations S133, S127 and S4 is mostly satisfied by our biweekly with flow sampling. The S352 station is currently sampled biweekly for grab samples and is also sampled weekly by a flow proportional autosampler. C2 also involves the HGS6 station. HGS6 is the lock structure at Taylor Creek and there are several errors related to the incorporation of this site. The HGS6 site is not sampled by the District as stated in the report, and it is not a hydrological connection to S191. Since this document averaged the data from HGS6 with S191, the finding that HGS6 is one of the significant contributors to the variance in load may be inaccurate. The C3 alternative calls for the installation of autosamplers at S191, S65E, S154, S84, S71, FEC, S77, S310, S3, S2, and S308C. Five of these stations are equipped with autosamplers (S191, S65E, S154, S2 AND S3) and as stated earlier, S77 and S308C are major outflows from the lake and are not used in the District's load calculation model. The benefits of increased sampling at S77 and S308C would need to be evaluated for the calculation of annual nutrient budgets. Stations S84 and S71 are currently sampled biweekly regardless of flow and this additional sampling may reduce the uncertainty that Gain found. The S310 station is a lock structure that is located within a commercialized area (marinas, etc.) that the District decided to sample further upstream (INDUSCAN) in an effort to avoid the influences of these operations. The site with the most potential to produce the load calculation benefits prescribed by Gain, may be the Fisheating Creek station (FECSR78). Due to this sites' historically high contribution of flow to the lake, it is also an important factor in load calculations and increased data collections via autosampler may be worthwhile. Gain's document is currently being evaluated by District staff.

C. LOOP (Class I/III) Issues

The Lake Okeechobee Operating Permit (LOOP) is currently in a renewal process that has been ongoing since 1988. The District and FDEP were scheduled to complete this phase by 1992, but this effort has been hindered by changes in staffing priorities and the inability to arrive at a solution to resolving the FDEP's concern over exceedances to the Class I/III standards inherent to the permit. The CH2M HILL *Lake Okeechobee Class I/III Water Quality Study* was mandated in the 1989 SWIM Plan and reviewed historical water quality data for the lake. This study used all the data collected between November 1973 and October 1991 from 33 of the X Project stations. Data from a supplemental study conducted by CH2M HILL and flow proportional autosampler data from the Special 298 Drainage District stations (CULV4A, CULV10, CULV12 and S236) were also included in the statistical analyses. Although the findings of this study

revealed that the water quality of these tributaries was generally in compliance with the state's Class I/III standards, several exceedances to the legal standards for concentrations of certain parameters (especially dissolved oxygen) were also identified. Based on the CH2M HILL study, the FDEP has required that the District make concessions to reduce the level of exceedances identified in the report, before a new permit will be issued.

In many cases, the ability to find workable solutions to these exceedances is limited by the nature of the tributaries in question. CH2MHILL found that many of the exceedances were due to natural causes within the watershed and should would not be considered a violation in terms of the State Water Quality Standards. The ratings system may need to be adjusted for the presence of natural background effects on the concentration levels of certain variables, especially during differing flow scenarios. A more thorough knowledge of how the data collected may be influenced by a monitoring program that is driven by scheduling (instead of events) is also needed. The current grab sampling method can only provide a snapshot of the physical nature of these water bodies and parameters such as dissolved oxygen are influenced by temporal, seasonal and site specific factors that may not be fully reflected in the data. The 1997 SWIM Plan details some potential management strategies for reducing exceedances. These include oxygen injection, sediment removal and mixing zones. These options should be thoroughly evaluated for efficiency in achieving the desired goals and for cost effectiveness.

V. RECOMMENDATIONS

This document is not intended to be a statistical analysis from which to justify project modifications. Recommendations for revisions are based on knowledge of how this data set is used and the legal requirements that determine many of the current design features. The development of this document has provided a clearer assessment of the effectiveness of the current project design. This effort uncovered several monitoring and managerial issues that have been addressed during the course of this analysis or await resolution subsequent to the distribution of this document. On-going efforts to maximize the efficiency of the Water Quality Monitoring Division have also provided an impetus to put forth options for scientifically sound, more cost effective methods for water quality sampling of Lake Okeechobee inflows and outflows. These options and monitoring issues are presented here for review:

- 1) Improvements suggested in the Lettenmaier and Gain reviews must be evaluated on both a statistical and informational basis. The scope of these two studies was too limited to allow for wide scale changes in this monitoring program. Many of the recommendations would have affected other research and management objectives. The incurred expense of incorporating additional monitoring for the benefit of minor reductions in total phosphorus load error would need to be evaluated on a managerial level. Also, both reviews used a net load perspective to develop their optimized networks. Since we are currently following the modified Vollenweider model loading target, which is based on inflows only, the increased frequency and instrumentation of primary outflows (e.g. S308C and S77) would need to be

evaluated separately for the benefits to nutrient budget calculations. Also, the total load error reduction and cost benefit analysis derived by Gain was based on a sampling frequency (two times per year) that is far below what is achieved under the X Project. The recommendation to utilize trained observers would represent an extreme departure from the current District standard of relying on skilled technicians to collect samples for a project of this magnitude and significance. However, such a volunteer network could be a useful tool for augmenting data collection during storm events and for Total Maximum Daily Load (TMDL) considerations. With a few exceptions, our current level of monitoring approximates or exceeds the recommendations of both reviews. Therefore, the costly and time consuming exercise of utilizing the methodologies of these reviews for a wide scale re-analysis of the current data set is probably not needed. However, the analysis of certain sites that were given a higher weight of importance than what the current monitoring design accounts for, would be practical.

Recommendations:

- a) Using a more current data set (concentration and flow), reevaluate the significance of stations *S4*, *INDUSCAN*, and *FECSR78* to the load to the lake and determine if increased sampling frequencies and instrumentation are justified.
 - b) The importance of net loading and any added insights that this calculation could contribute to the lake's management should be evaluated. Although the current policies for load calculations do not call for this type of analysis, the focus of these two reviews did place a considerable amount of relevance on the incorporation of this aspect of water quality into our lake management program.
 - c) The District must ensure that any future project reviews or optimization efforts will consider the legal requirements and informational goals of the reviewed project. Reviews that merely develop high powered statistical analyses of data are not functional documents and managers are left powerless to implement recommendations that are not feasible to the total scope of a project. Outside reviews would be more practical if statistical analyses were combined with in depth knowledge of all legal and informational requirements of the specific project.
- 2) The Okeechobee Division has recommended that no reductions (sites or parameters) be applied to the X Project at this time. However, certain sites may no longer meet the data objectives for which they were originally established. For example, C38W, L59E and L61E have had no recorded flow into the "lake" for several years and L61E has been refitted with a pump that only allows for water movement out of Harney Pond. It has also come to light that the mandatory biweekly monitoring of stations S191, S84, S154 and S71 was implemented because of their significant contributions to the load to the lake, with

total phosphorus being the only variable of concern.

Recommendations:

- a) Evaluate the contributions of C38W, L59E and L61E to the load to the lake. Investigate the hydrological connections of these sites to other X Project stations and determine if there is repetitive sampling occurring among sites. Distribute a memo with findings and recommendations for possible reductions or eliminations to data users and gain consensus on the most proper course of action.
 - b) Samples collected at S154, S71, S84 and S191 when there is no flow could be analyzed for total phosphorus (TP) only. The full compliment of parameters would still be collected on a monthly basis, but when a sample is collected during a condition that would not be normally be sampled at the other stations (i.e. collecting samples on a flow trip when there is no flow), TP could be the only variable analyzed. The elimination of the parameters TKN, TURB, TSS, NOX, NH4, COLOR, OPO4, NO2, CL and ALK on a mandatory biweekly basis would result in a potential reduction of 464 analyses per year and would not violate any known legal requirements. Distribution of this recommendation to all potential end users would determine if these eliminations would compromise any research objectives.
- 3) A stronger effort to renew the LOOP should be initiated within the District. This will require a comprehensive effort between the FDEP and among several District divisions and departments.

Recommendations:

- a) Designate a liaison to work with FDEP and develop reasonable solutions (technical and information based) to reducing the violations to the Class I/III standards. Staff members who are familiar with this permit and the area it covers, should be active in the development of the new permit. This will ensure that any revisions to monitoring projects or demands for water quality management strategies, can be reasonably met.
 - b) Develop an improved reporting format that provides a more appropriate representation of compliance to regulatory requirements.
- 3) An increased monitoring strategy has been developed for the EAA outflow stations on the southern end of the lake. This effort includes the installation of automatic samplers at S351 and S354, as well as the establishment of a new upstream sampling site at S352. The proposed scope of work has been distributed to District staff members and has passed initial review. The current S352 grab and automatic samples are collected on the downstream side of this structure. There are a total of five inputs between the structure and these sampling locations. The culverts and

seepage canals drain the residential and industrial non-point sources of Canal Point. It is suspected that elevated nutrient concentrations obtained from these sites are the result of influences from these sources. The autosampler site is equipped with a UVM that triggers the unit to collect samples when flow is detected. It was initially believed that a registered flow would only occur when the gates at the S3252 structure were open and water from the lake was being released. However, even when the gates are closed, the UVM has been detecting flow and triggering sample collection. This is most likely due to draw down effects caused by the pumping of the WPB Canal waters into agricultural areas. The objective of these sites is to supply data that represent the source of water being delivered to the EAA from Lake Okeechobee. The current locations of these sampling stations may not be meeting their informational objectives. Concerns over historical data consistency should not outweigh the importance of representative data.

Recommendations:

- a) If the data obtained from the upstream (lake side) S352 monitoring site are significantly different from those obtained from the historical sampling locations, the downstream sites should be discontinued (grab and automatic). The upstream grab sampling station (S352UP) should be maintained and the collection of the total X Project parameter list should be initiated from this location. The autosampler should also be relocated and instrumented with RACU technology that will trigger sample collection when the gates at the structure are opened.
- b) The database should reflect that the historical data collected from these locations were collected downstream and may not represent the information objectives of this site. This could be achieved by renaming the downstream stations for all associated period of record data.

Author's Note: These recommendations have been initiated as of 6/1/98 with the permission of all pertinent District Departments. The current sampling at this site involves biweekly upstream and downstream grabs and the downstream autosampler has been moved upstream. The autosampler is triggered to collect flow proportional samples only when the structure gates are open. All historic downstream autosampler data is now coded as **S352AS** in the database.

- 4) Given the intricate nature of some of our monitoring programs, it is essential that project managers have a clear understanding of how the data they are using is being collected. The initiation of extensive modeling efforts has greatly increased our ability to establish and project water quality trends for this watershed, but the modelers often make many assumptions regarding the actual data being collected. Researchers and modelers need to establish a rapport with the staff who collects the data for them. The following recommendations are put forth in an effort to

reestablish the essential connection between the functions of data collection and use.

Recommendations:

- a) Clearly identify the responsibilities of project managers and encourage end users to establish a working relationship with the field technicians. This will ensure project consistency and support an attitude of involvement that is beneficial to all.
- b) Develop a more concise and effective method for data review and a more consistent protocol for flagging data (lab vs. field and fatal vs. non-fatal flags). This will also facilitate an atmosphere of involvement on all levels and increase the quality of data.
- c) Intensify requirements for presentation of data to staff and public. The target audiences for this information are varied and the reporting formats should be consistent with the needs and level of expertise of these groups. Essential information for the research oriented groups would include comments on data usability (e.g. if a data point that may not be consistent with the historical water quality is not fatally flagged from the data base, users should be made aware of the circumstances under which that sample was collected by inclusion of field log notes). These users would then have the knowledge needed to decide if they want to include that data in their specific analysis. The types of information presented to the governing board or public groups should clearly state the implications of the data. These types of reports should include graphical representations and scientific explanations for watershed trends.

VI. CONCLUSIONS

This system design document has furnished a better understanding of the demands placed on the X Project and provides a base of information to draw from when making any future decisions regarding this project. The information contained in this document allows any proposed revisions to take into account all of the requirements of this project and should be used to ensure that no legal or research objectives are compromised by future modifications. Budgetary restraints must also be taken into consideration when projecting long term uses of water quality monitoring programs. Based on the history of change associated with the X Project, it is evident that a monitoring effort of this magnitude does not lend itself to a static existence. With the onset of new legal requirements (LOOP renewal) and proposals for hydrological re-engineering (C&SF Restudy) within the watershed, it is likely that revisions to this project will be necessary.

The Lake Okeechobee restoration and management efforts are part of a long-term mission that will be continued for years to come. This longevity ensures that the X Project will remain a critical component of the District's monitoring network. As political and social perspectives toward the ecological state of South Florida continue

to evolve, the demand for premium water quality data, as it applies to compliance, load calculations and management plans within the LOK watershed, is likely to intensify. In order to uphold the responsibility of monitoring and managing the water quality and overall ecological health of Lake Okeechobee, our research directives will have to respond appropriately to any future anthropogenic activities and attitudes that may affect the lake and its watershed areas. As one of the dominant water quality data sources utilized in fulfilling these objectives, the scope of the X Project must also progress accordingly.

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LIST OF APPENDICES

Appendix A: Structure descriptions and operating criteria for selected X Project monitoring stations.

Appendix B: Level one landuse for the source drainage basins of X Project sampling sites.

Appendix C: Copy of Lake Okeechobee Inflow/Outflow Monitoring Program Questionnaire/Survey and participant responses.

APPENDIX A

**Structure descriptions and operational criteria for the following Lake Okeechobee
Inflow/Outflow Monitoring Program Sampling Stations:**

- 1. CULVERT 10 (CULV10)**
- 2. CULVERT 10A (CULV10A)**
- 3. CULVERT 4A (CULV4A)**
- 4. CULVERT 5 (CULV5)**
- 5. S-127**
- 6. S-129**
- 7. S-131**
- 8. S-133**
- 9. S-135**
- 10. S-154**
- 11. S-154C**
- 12. S-191**
- 13. S-2**
- 14. S-236**
- 15. S-3**
- 16. S-308C**
- 17. S-352**
- 18. S-4**
- 19. S-65E**
- 20. S-71**
- 21. S-72**
- 22. S-77**
- 23. S-84**

CULVERT 10 (CULV10)

This structure is a double barreled corrugated culvert located between S-352 and S-351 through LD-2 Levee. Control is effected by flap gate located on the Lake Okeechobee side of the structure.

Access

Structure is located on Levee LD-2 between S-352 and S-351.

Purpose

This structure provides flood control and irrigation water for the East Beach Drainage District.

Operational Criteria

The structure is operated by the Corps of Engineers' Clewiston office. East Beach Drainage District has a pumping station connecting to this structure through a short canal. For drainage, water is pumped into Lake Okeechobee through the canal and this structure. The flap gates prevent water from the Lake backing into the canal. For irrigation releases from Lake Okeechobee, the flap gate can be lifted manually to release water to the pumping station. Water can be discharged through the trough or the pump in the pumping station. The trough discharge capacity is 4.7 acre-feet per hour at lake stage 12.5 feet and the pumping capacity of each pump is 8.3 acre-feet per hour as measured on December 13, 1989.

Hydraulic and Hydrologic Measurements

Water Level: Upstream and downstream staff gauge.

Rain Gauge: None

CULVERT 10A (CULV10A)

This structure is a five-barreled corrugated metal pipe culvert located at the north end of the L-8 canal through the Herbert Hoover Dike.

Access

Structure located at L-8 crossing of U.S. 441.

Purpose

The purpose of this structure is to provide irrigation releases from Lake Okeechobee to the agricultural lands along the L-8 canal and to afford gravity drainage of that canal into Lake Okeechobee during flood periods, when the Lake is lower than the canal. It also affords some measurement of water supply to the East Coast area of Palm Beach County.

Operational Criteria

Operation of this structure is performed by the Corps of Engineers. District requests for irrigation releases are made through the Clewiston Office of the Corps. Based on the recommendation of the District's environmental science division, the minimum gate opening of this structure has to be above 2.5 feet or closed completely to protect manatees.

The water supply operation is as follows:

One or more gates at Culvert 10A will be opened full to maintain stage in L-8 between 12 - 14. When the stage at L-8 at S-5A falls below 12.0 and the stage in CA-1 is not too low, S-5AS will be partially opened as required to maintain the 12.0 stage in L-8 and S-5A. Because of water quality concerns regarding WCA1, Culvert 10A should supply water to the City of West Palm Beach pumping station on L-8 Canal if water in WCA1 is of poor quality. During hurricane alerts, Culvert 10A slide gate will be closed.

Flood Discharge Characteristics

Design Discharge Rate: 1000 cfs *

Headwater Elevation: 19.0 (land side)

Tailwater Elevation: 15.6 (lake side)

Water level which will by-pass structure: 34 feet

* Note: Design not related to Standard Project Flood

Hydraulic and Hydrologic Measurements

Water Level Recorder: Downstream (land side) and upstream (lake side) staff gauge only.

Gate Position Recorder: None

CULVERT 4A (CULV4A)

This structure is a double barreled corrugated culvert located between S-2 and S-3, through LD-2 Levee. Control is effected by flap gate located on the Lake Okeechobee side of the structure.

Access

Structure is located on Levee LD-2 between S-2 and S-3.

Purpose

This structure provides flood control and irrigation water for the South Shore Drainage District.

Operational Criteria

The Structure is operated by the Corps of Engineers' Clewiston office. South Shore Drainage District has a two unit pumping station connecting to this structure through a short canal. For drainage, water is pumped into Lake Okeechobee through the canal and this structure. The flap gates prevent water from the Lake backing into the canal. For irrigation releases from Lake Okeechobee, the flap gate can be lifted manually to supply water to the pumping station. Water can be discharged through the pumping station by two 6 foot weirs or the pump. Each weir is 6 feet wide and its crest is determined by the number of flash boards in place. The measuring point for the boards is at elevation 20.08 feet above mean sea level. The pumping capacity of each pump is 8.3 acre-feet per hour as measured on December 13, 1989.

Hydraulic and Hydrologic Measurements

Water Level: Upstream and downstream staff gauge.

Rain Gauge: None

CULVERT 5 (CULV5)

This structure is a three barreled corrugated metal pipe culvert located at the mouth of Nicodemus Slough, through the LD-3 Levee. Contract No. 88-148-0722 Drawing No. 56-028

Access

Structure is located at LD-3 crossing of SR #78.

Purpose

The purpose of this structure is to provide releases from Lake Okeechobee to the lower reaches of Nicodemus Slough and to afford gravity drainage of that slough into Lake Okeechobee during flood periods when the Lake is lower than the slough.

Operational Criteria

The structure will be operated by the District. The normal operation is a function of the level of Lake Okeechobee and the Nicodemus Slough Schedule as depicted on the accompanying charts. If the water level on the land side of Culvert 5 is greater than the Nicodemus Slough Schedule and greater than the level on the lake side, one or more gates will be opened to lower the level of the Nicodemus Slough Schedule. If the land side level is below the schedule and below the lake side level, one gate will be opened to try to bring the level in the slough up to its schedule.

Drainage Area Flood Discharge Characteristics

Design Inflow Rate: 1621 cfs

Design Storm Recurrence Interval: 10 years

Water level which will by-pass structure: 34 feet

Hydraulic and Hydrologic Measurements

Water Level Recorder: Upstream and Downstream Staff Gauges and remote digital recorders

Gate Position Recorder: None

S-127

Structure 127 is located on the northwest shore of Lake Okeechobee in the alignment of Levee 48. It is just south of State Road 78 and about 12 miles southwest of the town of Okeechobee. This structure consists of a pumping plant and navigation lock. The pumping plant has one gated spillway consisting of a corrugated metal pipe culvert which controls flows which bypass the pumps. The pumping plant consists of both a pumping and an outlet unit. The pumping unit is a reinforced concrete structure with a concrete block superstructure. The outlet is a U-shaped structure of reinforced concrete sides and bottom. The pumping plant is equipped with five 125 c.f.s. pumps.

Access

From State Road 27 via about 3/4 miles of access road.

Purpose

Lake Okeechobee Northwest Shore Levees, together with higher lake stages, restrict natural drainage to the lake. This structure, together with S-129 and S-131, removes the otherwise impounded water at the rate of as much as 3/4 inch runoff per day from the tributary drainage area.

Operational Criteria

The spillway will be used to allow gravity discharge during periods when Lake Okeechobee stage is below elevation 13.0. This pipe spillway can also be used during drought conditions to provide water for the tributary area when the lake stage is above the intake canal water level. Normally, pumping will be initiated when the headwater elevation reaches 14.0 and terminated when it drops to 13.5. However, if heavy rainfall is predicted, which is expected to raise the headwater stage above 14.0, all pumping units will be placed in operation and the stage lowered to and maintained at elevation 13.0 until after the storm has passed. The spillway gate shall be closed at all times when the lake level is above intake canal water level except when backflow for irrigation purposes is desirable during a drought period. For the normal range of pumping heads up to 4.5 feet, the engine should be run at a constant governed speed of 1085 r.p.m. For pumping heads of 4.5 feet to 10.5 feet, the engine speed should be 1200 r.p.m. At these two head ranges and speed ranges, the pumps will be operating approximately as shown on the Operation Chart. After the pump is stopped, the vacuum breaker valve may be opened to permit the water column in the pump to drop to pool level and the water in the discharge pipe to drop to the lower of the lake or invert elevation. Whenever the lake stage is below 14.0 feet, the lock remains full open. When the lake exceeds this stage, the lock is operable seven days a week between 5:30 AM and 8:00 PM, and the lock is full closed between 8:00 PM and 5:30 AM.

Flood Discharge Characteristics

Pump Design

Discharge Rate: 630 cfs

Headwater Elevation: 13.0 feet

Tailwater Elevation: 23.5 feet

Type Discharge: pumped

Hydraulic and Hydrologic Measurements

Water Level On-site, dual recorder

Gate Position Recorder None

Date of Transfer: December 14, 1965

S-129

Structure 129 is located on the northwest shore of Lake Okeechobee in the alignment of Levee 49. It is just south of State Road 78 and about 20 miles southwest of the town of Okeechobee. This structure is a pumping plant, consisting of three pumping units and a corrugated metal pipe culvert spillway which controls flows which bypass the pumps. The structure consists of a pumping and an outlet unit. The pumping unit is a reinforced concrete structure with a concrete block superstructure. The outlet unit is a U-shaped structure of reinforced concrete sides and bottom.

Access

From State Road 27 via about 1 mile of access road.

Purpose

Lake Okeechobee Northwest Shore Levees, together with higher lake stages, restrict natural drainage to the lake. This structure, together with S-127 and S-131, removes the otherwise impounded water at a rate of as much as 3/4 inch of runoff per day from the tributary drainage area.

Operational Criteria

The spillway will be used to allow gravity discharge during periods when Lake Okeechobee stage is below elevation 13.0. This pipe spillway can also be used during drought conditions to provide water for the tributary area when the lake stage is above the intake canal water level. Normally, pumping will be initiated when the headwater elevation reaches 13.5 and terminated when it falls to 13.0. However, if heavy rainfall is predicted, which is expected to raise the headwater stage above 13.5, all pumping units will be placed in operation and the stage lowered to and maintained at 12.5 until the storm has passed. The spillway gate shall be closed at all times when the lake level is above intake canal water level except when backflow for irrigation purposes is desirable during a drought period. For the normal range of pumping heads up to 4.5 feet, the engine should be run at a constant governed speed of 1085 r.p.m. For pumping heads of 4.5 feet to 10.5 feet, the engine speed should be 1200 r.p.m. At these two head ranges and speed ranges, the pump will be operating approximately as shown on the Operation Chart. After the pump is stopped, the vacuum breaker valve may be opened to permit the water column in the pump to drop to pool level and the water in the discharge pipe to drop to the lower of the lake or invert elevation.

Flood Discharge Characteristics

Pump Design

Discharge Rate: 375 cfs

Headwater Elevation: 13.0 feet

Tailwater Elevation: 23.5 feet

Type Discharge: Pumped

Hydraulic and Hydrologic Measurements

Water Level: On-site, dual recorder

Gate Position Recorder: None

Date of Transfer: December 14, 1965

S-131

Structure 131 is located on the northwest shore of Lake Okeechobee in the alignment of Levee 50. It is just south of State Road 78 and about 27 miles southwest of the town of Okeechobee. This structure consists of a pumping plant and a navigation lock. The pumping plant has one gated spillway consisting of a corrugated metal pipe culvert which controls flows which bypass the pumps. The pumping plant consists of both a pumping and an outlet unit. The pumping unit is a reinforced concrete structure with a concrete block superstructure. The outlet unit is a U-shaped structure of reinforced concrete sides and bottom. The pumping plant is equipped with two 125 cfs pumps.

Access

From State Road 27 via about 1/4 miles of access road.

Purpose

Lake Okeechobee Northwest Shore Levees, together with higher lake stages, restrict natural drainage to the lake. This structure, together with S-127 and S-129, removes the otherwise impounded water at a rate of as much as 3/4 inch of runoff per day from the tributary drainage area.

Operational Criteria

The spillway will be used to allow gravity discharge during periods when Lake Okeechobee stage is below elevation 13.0. This pipe spillway can also be used during drought conditions to provide water for the tributary area when the lake stage is above the intake canal water level. Normally, pumping will be initiated when the headwater elevation reaches 13.5 and terminated when it falls to 13.0. However, if heavy rainfall is predicted, which is expected to raise the headwater stage above 13.5, all pumping units will be placed in operation and the stage lowered to and maintained at 12.5 until the storm has passed. The spillway gate shall be closed at all times when the lake level is above intake canal water level except when backflow for irrigation purposes is desirable during a drought period. For the normal range of pumping heads up to 4.5 feet, the engine should be run at a constant governed speed of 1085 r.p.m. For pumping heads of 4.5 feet to 10.5 feet, the engine speed should be 1200 r.p.m. At these two head ranges and speed ranges, the pump will be operating approximately as shown on the Operation Chart. After the pump is stopped, the vacuum breaker valve may be opened to permit the water column in the pump to drop to pool level and the water in the discharge pipe to drop to the lower of the lake or invert elevation.

Whenever the lake stage is below 13.5 feet, the lock remains full open. At this condition, canal level may be higher than the lake due to the sandbar in the area. When the lake exceeds this stage, the lock is operable seven days a week between 5:30 AM and 8:00 PM, and the lock is full closed between 8:00 PM and 5:30 AM.

Flood Discharge Characteristics

Pump Design

Discharge Rate: 230 cfs

Headwater Elevation: 13.0 feet

Tailwater Elevation: 23.5 feet

Type Discharge: pumped

Hydraulic and Hydrologic Measurements

Water Level On site, dual recorder, remote, telemetry

Gate Position Recorder None

Engine Tachometers Remote, telemetry

Date of Transfer: November 29, 1963

S-133

This structure is a five unit pumping plant located on the northeast shore of Lake Okeechobee landward of Herbert Hoover Dike and in the alignment of Levee D-4. It is lakeward of U. S. Highway 441 and about 3 miles southeast of the town of Okeechobee and about 1200 feet west of S-193 on Taylor Creek. The station consists of both a pumping and outlet unit. The pumping unit is a reinforced concrete structure with a concrete block superstructure. The outlet unit is a U-shaped structure of reinforced concrete sides and bottom. The pumping station is equipped with five 125 cfs pumps which discharge via the outlet structure into the lake.

Access

From U. S. Highway 441 via about 1,000 feet of access road.

Purpose

Lake Okeechobee Northeast Shore Levees, together with higher lake stages, restrict natural drainage to the lake. This structure, together with S-135, removes the otherwise impounded water at a rate of as much as 3/4 inch of runoff per day from the tributary drainage area.

Operational Criteria

As a means of providing for gravity discharge of runoff from the drainage areas to the lake when lake stages permit, the lock through Levee D-4 at S-193 satisfies the requirements for the area served by S-133. Normally, pumping will be initiated when the headwater elevation reaches 14.0 and terminated when it falls to 13.5. However, if heavy rainfall is predicted, which is expected to raise the headwater stage above 14.0, all pumping units will be placed in operation and the stage lowered to and maintained at 13.0 until the storm has passed. The lock shall be in operation at all times when the lake level is above the intake canal water level. For the normal range of pumping heads up to 4.5 feet, the engine should be run at a constant governed speed of 1,085 r.p.m. For pumping heads of 4.5 feet to 10.5 feet, the engine speed should be increased to 1,200 r.p.m. At these two operating speeds, the pump will be operating approximately as shown on the Operation Chart. After the pump is stopped, the vacuum breaker valve may be opened to permit the water column in the pump to drop to intake pool level and the water in the discharge pipe to drop to the lower of the lake or invert elevation.

Flood Discharge Characteristics

Pump Design

Lower Profile

Discharge Rate: 625 cfs

Headwater Elevation: 13.0 feet

Tailwater Elevation: 23.5 feet

Type Discharge: Pumped

Hydraulic and Hydrologic Measurements

Water Level: On-site, dual recorder

Gate Position Recorder: None

S-135

Structure 135 is located on the northeast shore of Lake Okeechobee in the alignment of Levee 47 at Chancy Bay. It is lakeward of U.S. Highway 441 and about 15 miles southeast of the town of Okeechobee. This structure consists of a pumping plant and a navigation lock. The pumping plant has a spillway consisting of two gated corrugated metal pipe culverts which control flows which bypass the pumps. The station consists of both a pumping and outlet unit. The pumping unit is a reinforced concrete structure with a concrete block superstructure. The outlet unit is a U-shaped structure of reinforced concrete sides and bottom. The pumping station is equipped with four 125 cfs pumps which discharge via the outlet structure into the lake. A navigation lock is located just south of the station. The lock was provided by local interests with funds other than project funds.

Access

From U.S. Highway 441 via about 1/4 mile of access road.

Purpose

Lake Okeechobee Northeast Shore Levees, together with higher lake stages, restrict natural drainage to the lake. This structure, together with S-133, removes the otherwise impounded water at a rate of as much as 3/4 inch of runoff per day from the tributary drainage area.

Operational Criteria

The spillway will be used to allow gravity discharge during periods when Lake Okeechobee stage is below elevation 13.0. This pipe spillway can also be used during drought conditions to provide water for the tributary area when the lake stage is above the intake canal water level. Normally, pumping will be initiated when the headwater elevation reaches 14.0 and terminated when it falls to 13.5. However, if heavy rainfall is predicted, which is expected to raise the headwater stage above 14.0, all pumping units will be placed in operation and the stage lowered to and maintained at 13.0 until the storm has passed. The spillway gate shall be closed at all times when the lake level is above intake canal water level except when backflow for irrigation purposes is desirable during a drought period. For the normal range of pumping heads up to 4.5 feet, the engine should be run at a constant governed speed of 1200 r.p.m. For pumping heads of 4.5 feet to 10.5 feet, the speed should be 1200 r.p.m. At these two head ranges and speed ranges, the pumps will be operating approximately as shown on the Operation Chart. After the pump is stopped, the vacuum breaker valve may be opened to permit the water column in the pump to drop to pool level and the water in the discharge pipe to drop to the lower of the lake or invert elevation. Whenever the lake stage is below 14.0 feet, the lock remains full open. When the lake exceeds this stage, the lock is operable seven days a week between 5:30 AM and 8:00 PM, and the lock is full closed between 8:00 PM and 5:30 AM.

Flood Discharge Characteristics

Pump Design

Discharge Rate: 500 cfs

Headwater Elevation: 13.0 feet

Tailwater Elevation: 23.5 feet

Type Discharge: pumped

Hydraulic and Hydrologic Measurements

Water Level: On-site, dual recorder

Gate Position Recorder: None

S-154

This structure is a double-barreled reinforced concrete box culvert, located through Levee D4 about 5 miles west of Okeechobee. Control is effected by automatically operated sluice gates mounted on a reinforced concrete head structure.

Access

From State Road #70 at a point about 1.5 miles east of C-38 via Herbert Hoover Dike Road on the crest of L-D4.

Purpose

This structure maintains optimum upstream water control stages; it passes the design flood (30% of the Standard Project Flood) without exceeding the upstream flood design stage and restricts downstream channel velocities to non-damaging levels; and it prevents backflow from Lake Okeechobee during excessive stages in the lake caused by flood or wind tide.

Operational Criteria

This structure is operated to maintain the 23.3 foot optimum upstream stage insofar as possible through automatic controls as follows:

When the headwater elevation rises to 23.8 feet, the gates begin to open;

When the headwater elevation rises or falls to 23.3 feet, the gates become stationary;

When the headwater elevation falls to 22.8 feet, the gates begin to close.

When the tailwater rises to within 0.2 feet of the headwater, the gate closes to prevent backflow through the structure.

Flood Discharge Characteristics

Design Discharge Rate: 1000 cfs 30 % of SPF

Headwater Elevation: 20.1 feet

Tailwater Elevation: 19.1 feet uncontrolled

Type Discharge: submerged

Hydraulic and Hydrologic Measurements

Water Level: upstream and downstream dual recorder

Gate Position Recorder: on-site

Date of Transfer: December 10, 1965

NOTE: This structure was destroyed May 10, 1974 and was replaced August 6, 1974 by a fixed crest sheet pile weir 125 feet long with a weir elevation of 22.0. A rehabilitation of the original structure was begun in 1976, and was completed in October 1977.

S-154C

This structure is a single-barrel, concrete pipe culvert located through L-D4, about 5 miles west of Okeechobee. Control is effected by a submersible gate mounted on a concrete box inlet structure.

Access

From State Road #70 at a point about 1 • miles east of C-38 via Herbert Hoover Dike Road on the crest of L-D4.

Purpose

This structure maintains the optimum upstream water control stages; it passes the design flood without exceeding the upstream flood design stage. A downstream flap valve prevents backflow from Lake Okeechobee during excessive stages in the lake caused by flood or wind tides.

Operation

This structure is operated to maintain an optimum headwater elevation of 16.0 feet. It is opened full during hurricane alerts in order to pass the maximum discharge possible.

Flood Discharge Characteristics

Design Discharge Rate: Indeterminate CFS% of SPF

Headwater Elevation: 20.1 feet

Tailwater Elevation: 19.1 feet

Type Discharge: controlled submerged

Water level which will bypass structure 35.0feet

Hydraulic and Hydrologic Measurements

Water Level: upstream and downstream staff gauges only

Gate Position Recorder: none

S-191

The structure is located on Canal 59 at its junction with Levee D4 on the north shore of Lake Okeechobee. This structure is a reinforced concrete, gated spillway with discharge controlled by three cable operated, vertical lift gates. Operation of the gates is automatically controlled so that the gate hydraulic operating system opens or closes the gates in accordance with the seasonal operational criteria.

Access

From U.S. Highway 441 via access ramp on west side of structure.

Purpose

This structure maintains optimum water control stages in the upstream agricultural area; it passes the design flood (once in ten years frequency) without exceeding the upstream flood design stage, and restricts downstream flood stages and discharge velocities to non-damaging levels; it prevents flooding from hurricane tides on Lake Okeechobee; and it permits backflow up to 330 cfs to the north to meet agricultural water requirements.

Operational Criteria

This structure will be operated to maintain, insofar as possible, headwater elevations within 0.2 feet above and 0.2 feet below the 19.5 foot water level. The automatic controls function as follows:

When the headwater elevation rises to 19.7 feet, the gates will open at six inches per minute; but the gate opening will be governed by the Differential Head versus Gate Position Curve, and it will not exceed the maximum allowable opening position; When the headwater elevation rises or falls to elevation 19.5, the gates will become stationary; When the headwater elevation falls to 19.3 feet, the gate will close at six inches per minute.

Backflow Regulation:

In addition to maintaining optimum upstream control, as described above, the automatic controls on this structure have an overriding control which closes the gates, regardless of the upstream water level in the rare event that the tailwater pool elevation reaches or exceeds the headwater elevation.

Flood Discharge Characteristics

Design Standard Project Flood

Discharge Rate 7440 cfs -- cfs

* % SPF 100 % SPF

Headwater Elevation: 19.2 feet 23.0 feet

Tailwater Elevation: 18.6 feet 23.5 feet

Uncontrolled

Type Discharge: Submerged

* Design flood based on once in 10 years frequency and not related to the Standard Project Flood.

Hydraulic and Hydrologic Measurements

Water Level: On-site, dual-recorder

Gate Position Recorder: On-site

S-2

This structure is a four unit pumping plant located in the alignment of Lake Okeechobee South Shore Levee at the intersection of the Hillsboro and the North New River Canals with Lake Okeechobee, in the western section of Palm Beach County, 3.5 miles northwest of Belle Glade, Florida.

The pumping station is equipped with four Fairbanks Morse 144 inch diameter vertical lift pumps, each rated for 900 c.f.s. at 7.2 foot static head. Each pump unit is driven by a Fairbanks Morse Model 38D8- 1/8, 1160 Horsepower opposed piston Diesel engine. Priming of the main pumps is normally accomplished by an electric motor-driven Nash Model Vacuum Pump. Power for the station is supplied by three Detroit Diesel Model 6-71, 75 KW AC generators. Other station equipment includes a station service water system for washdown, a dewatering system for the intake bays to speed up the dewatering operation for inspection or maintenance, and an electric motor-driven trash rake for removing debris from the intake bay trash rack.

Purpose

The purpose of the structure is to pump surplus water into Lake Okeechobee via the Hillsboro and North New River Canals from the agricultural area south and east of the structure at the rate of 3/4 inch per day from the 180 sq. mile tributary drainage area.

Operational Criteria

The pumping station will be operated whenever water level at any point in the Hillsboro or North New River Canals within the agricultural area south of the structure exceeds the optimum elevation of 12.5 feet unless the water level in Lake Okeechobee is low enough to permit quantity discharge into the lake through the nearby S-351 at a desirable rate. The water surface should not be drawn down below elevation of 10.0 feet at the structure. Under design head of 7.2 feet pool to pool the pumping station capacity is 3,600 cubic feet a second.

Because of water quality concerns in Lake Okeechobee, at present, the station is operated according to the EAA Interim Action Plan S-351 shall be closed during pumping operations. The pumps should be started and stopped slowly, one at a time, so that high velocities and surges will not occur in the Hillsboro or North New River Canals. The Operation Chart defines the entire recommended range over which pumping can be accomplished. Inasmuch as the reduction ratio between engine and pump is fixed, all pump rotative speeds are expressed in the engine speed which is indicated on the engine tachometer. The rated speed is 625 r.p.m. At this speed, the pumps will pump 900 c.f.s. or greater with pool to pool heads not in excess of 7.2 feet and intake pool stage between elevation 13 and 9.5. Should pumping be required at pool to pool heads, between 7.2 and 10.0 feet, such pumping may be accomplished at rated speed and a resultant reduced flow, provided at the higher heads the engine temperatures do not exceed permissible maximums. Should this occur, the engine speed should be reduced.

The pumps in this station are designed to pump drainage water containing a negligible amount of sediment or other material which might damage the surface of the pump or the bearings. All pump bearings are designed for grease lubrication and to exclude dirt and grit. However, the quantity of water being pumped by the station should be reduced at any time the water in the suction bay becomes moderately silted or if it appears that the approach velocities are carrying a bottom load of sand or silt into the sump chambers.

Flood Discharge Characteristics

Discharge rate: 3600 cfs

Headwater Elevation: 13.0 feet

Tailwater Elevation: 19.2 feet

Hydraulic And Hydrologic Measurements

Water Level Remote digital recorders and staff gauges at upstream and downstream

Gate Position Recorder: None

Engine Tachometer: Digital, on-site and remote, recorder

Date of Transfer: February 1, 1957

S-236

This structure is a three unit pumping station located on the southwest shore of Lake Okeechobee, about 2 miles southeast of Clewiston, Florida. The station consists of both a pumping and outlet unit. The pumping unit is a reinforced concrete structure with a concrete block superstructure and it is on the landside of the Lake Okeechobee Levee LD-2. The pumping station is equipped with three vertical axial flow pumps each rated for 85 c.f.s. at 11.0 foot static head. Each pump is driven by a 325 horsepower diesel engine, which discharges via the outlet structure into the lake. The outlet unit is a U-shaped structure of reinforced concrete sides and bottom.

Access

From State Road No. 80 via about 80 ft. of paved access road.

Purpose

This structure provides for drainage previously discharged directly into the lake by local Pumping station No. 5. This local pumping plant cannot operate efficiently with the newly authorized increase in the Lake Okeechobee regulation levels to 19.5-21.5 feet. S-236 pumps surplus water into Lake Okeechobee from the agricultural area generally to the southwest of the structure, in Palm Beach and Hendry Counties.

This surplus consists of seepage through the LD-2 Levee and runoff at the rate of 3/4 inch per day from the 10.2 square mile tributary drainage area.

Operational Criteria

Normally, pumping will be initiated when the headwater reaches 9.7 feet and terminated when it reaches 7.5 feet. However, if heavy rainfall is predicted, which is expected to raise the headwater stage above 9.7 feet, all pumping units will be placed in operation and the stage lowered to and maintained at 7.5 feet until the storm has passed. After the pump is stopped, the vacuum breaker valve may be opened to permit the water column in the pump to drop to intake pool level and the water in the discharge pipe to drop to the lower of the lake or invert elevation. This structure is operated and maintained by the South Florida Conservancy District.

Flood Discharge Characteristics

Pump Design

Discharge Rate: 255 cfs

% SPF

Headwater Elevation: 7.5 feet

Tailwater Elevation: 18.5 feet

Hydraulic and Hydrologic Measurements

Water Level: On-site dual recorder

Gate Position Recorder: None

S-3

This structure is a three unit pumping plant located in the alignment of Lake Okeechobee South Shore Levee, at the intersection of the Miami Canal with Lake Okeechobee, in the western section of Palm Beach County just north of the town of Lake Harbor, Florida.

The pumping station is equipped with three Fairbanks Morse Company 144 inch diameter vertical pumps each rated for 890 c.f.s. at 6.6 feet static head. Each pump unit is driven by a Fairbanks Morse Model 38D8-1/8, 960 Horsepower, in-line diesel engine. Priming of the main pumps is accomplished by an electric motor driven Nash Model L-6, 520 c.f.m. vacuum pump. Power for the station is furnished by two 100KW AC General Motors, Model 6-110 generators.

Other station equipment includes a water system for washdown, a dewatering system for the intake bays for inspection and maintenance, and an electrically-operated hoist trash rake with compressed air control rake teeth for removing debris from the intake bay trash rack.

Purpose

The purpose of the structure is to pump surplus water from the agricultural areas to the south, into Lake Okeechobee, via the Miami Canal at the rate of 3/4 inches per day from the 129 sq. mile tributary drainage area.

Operational Criteria

The pumping station will be operated whenever the water level in the Miami canal within the agricultural area southerly of the pumping station exceeds 12.5 feet unless the water level in Lake Okeechobee is low enough to permit gravity discharge into the lake through S-354 at a desirable rate. The water surface should not be drawn below elevation 10.0 at the pumping station. Under design head, the capacity of Pumping Station 3 is 2,580 c.f.s. The pumps should be started and stopped slowly, one pump at a time, so that high velocities and surges will not occur in the Miami Canal. S-354 should be closed during pumping operations.

Because of water quality concerns in Lake Okeechobee, at present, the station is operated according to the EAA Interim Action Plan. The Operation Chart defines the entire recommended range over which pumping can be accomplished. Inasmuch as the reduction ratio between engine and pump is fixed, all pump rotative speeds are expressed in terms of engine speeds which are indicated on the engine tachometer. The rated speed is 715 r.p.m. At this speed each pump has a design capacity of 860 c.f.s. or greater with pool to pool heads not in excess of 6.4 feet and intake pool gauge between Elevation 13.0 and 10.3.

The pumps in this station are designed to pump drainage water containing a negligible amount of sediment or other material which might damage the surface of the pump or bearings. All pump bearings are designed for grease lubrication and to exclude dirt and grit. However, the quantity of water being pumped by the station should be reduced at any time the water in the suction bay becomes moderately silted or if it appears that the approach velocities are carrying a bottom load of sand into the sump chambers.

Flood Discharge Characteristics

Discharge Rate: 2580 cfs

Headwater Elevation: 13.0 feet

Tailwater Elevation: 19.4 feet

Hydraulic and Hydrologic Measurements

Water Level Remote digital recorder

Gate Position Recorder: None

Engine Tachometer: Digital, on-site and remote recorders

Date of Transfer: April 7, 1958; floodwalls May 15, 1963

S-308C
Port Mayaca Lock and Spillway

The structure is located at the head of the St. Lucie Canal on the east shore of Lake Okeechobee. This structure is a reinforced concrete, gated spillway with discharge controlled by four cable operated, vertical lift gates and a reinforced concrete lock with two sets of sector gates.

Access

This site is reached via U.S. 441.

Purpose

This structure and S-77 provide the principal outlet capacity of Lake Okeechobee. The combined capacity of the Lake Okeechobee outlets provide for passing the 100-year and standard project floods without exceeding the lake flood design stage, and restricts downstream flood stages and channel velocities to non-damaging levels. This structure provides means for passing boat traffic between Lake Okeechobee and the St. Lucie Canal. It also prevents hurricane tides on Lake Okeechobee from entering the St. Lucie Canal.

Spillway Operating Criteria

This structure is operated and maintained by the U.S. Corps of Engineers. Moderate flood control releases are made whenever the lake schedule is exceeded by one foot or less. Full design releases are made when the lake is exceeded by more than one foot. During all other times, the structure is used to maintain a tailwater stage of 14.5 feet, as water is available.

Lock Operating Criteria

This structure is operated and maintained by the U. S. Corps of Engineers. The lock gates are opened full whenever the Lake Okeechobee stage is below elevation 14.5 feet. When the lake stage is above elevation 14.5 feet, the locks are operated between 6:00 a.m. and 10:00 p.m. daily; between 10:00 p.m. and 6:00 a.m. the lock gates are closed.

Flood Discharge Characteristics

Interim Design/Ultimate Design

Standard Project Flood

Discharge Rate: 14,800 cfs 17,000 cfs

Headwater Elevation: 24.9 feet 28.0 feet

Tailwater Elevation: 23.2 feet 24.5 feet

Type Discharge: Submerged, controlled

Water Level which will by-pass structure: 32 feet (over lock gate)

Hydraulic and Hydrologic Measurements

Water Level: On-site, dual-recorder

Gate Position Recorder: On-site

S-2 (S-351)

Structure S-351 is a reinforced concrete, gated spillway, with three vertical lift gates, located in L-D2, the perimeter dike of Lake Okeechobee, at the north end of the Hillsboro and North New River Canals. It is a replacement for Hurricane Gate Structure (HGS)-4. The structure was completed on March 22, 1989.

Access

From SR 80 crossing of North New River at South Bay via 2 miles of paved road on top of levee on west side of North New River Canal.

Purpose

This structure will permit releases to be made from Lake Okeechobee to meet water requirements in the Hillsboro and North New River service areas. It will permit flood flows to be discharged from the Agricultural Area into Lake Okeechobee when the lake level is low. It will also prevent hurricane tides from entering the Hillsboro or North New River Canals. It will be used, under certain conditions, to make regulatory releases from Lake Okeechobee into Water Conservation Area 2 via the North New River Canal and WCA 1 via the Hillsboro Canal.

Operational Criteria

The gates will normally be closed. They will be opened for three purposes:

- 1) To meet agricultural requirements in the area served by the Hillsboro or North New River Canals between Lake Okeechobee and the Water Conservation Areas or to meet requirements in the Coastal Area of Broward and Dade Counties, Everglades National Park, etc. These requirements generally occur in the dry season between mid-October and mid-May. The former requirement is gauged by a dry season stage below 11.5 feet in the Hillsboro or North New River Canals in the Everglades Agricultural Area (EAA) along with other factors.
- 2) To discharge flood flows from the Everglades Agricultural Area in the Hillsboro or North New River Canal when Lake Okeechobee is low (generally below 11.5 feet). Such occasions are very rare but could occur in the late spring.
- 3) When Lake Okeechobee is above schedule, when weather conditions are dry in the EAA, when canal stage in the Hillsboro and North New River Canals are low (generally below 11.5 feet) and when the stage in Water Conservation Area 2 is below schedule. Such occasions are also very rare.

Flood Discharge Characteristics

Design Standard Project Flood

Discharge Rate: 1500 cfs 2400 cfs

Headwater Elevation: 10.5 feet 24.5 feet

Tailwater Elevation: 10.0 feet 13.5

Maximum Hurricane Tide Elevation: 31.5 feet

Wave run-up (above hurricane tide): 7.8 feet

Water Level which will by-pass structure: 38.0 feet

Hydraulic and Hydrologic Measurements

Water Level: On-site, upstream and downstream analog recorders and remote digital recorders at S-2

Gate Position Recorder: On-site analog recorders

Rain Gauge: On-site analog recorder at S-2

Discharge: U.S.G.S. flow instruments in North New River and Hillsboro Canals

S-352

This structure is a reinforced concrete, gated spillway, with two vertical lift gates, located in L-D9, the perimeter dike of Lake Okeechobee, at the north end of the West Palm Beach Canal at Canal Point. It is a replacement for Hurricane Gate Structure (HGS)-5. The structure was completed on March 22, 1989.

Access

Structure located adjacent to U.S. 98 at Canal Point

Purpose

This structure will permit releases to be made from Lake Okeechobee to meet water requirements in the West Palm Beach Canal service areas. It will permit flood flows to be discharged from the Agricultural Area into Lake Okeechobee when the lake level is low. It will also prevent hurricane tides from entering the West Palm Beach Canal. It will be used, under certain conditions, to make regulatory or water supply releases from Lake Okeechobee into coastal Palm Beach County or Water Conservation Area 1.

Operational Criteria

The gates are normally closed. They are opened for three purposes:

- 1) To meet agricultural requirements in the area served by the West Palm Beach Canal between Canal Point and S-5A, or to meet requirements in the Coastal Area east of S-5A. These requirements generally occur in the dry season between mid-October and mid-May. The former requirement is gauged by a dry season stage below 11.0 feet between Canal Point and S-5A, along with other factors. The latter requirement is gauged by a dry season stage below 8.0 feet at S-155.
- 2) To discharge flood flows from the Agricultural Area between S-5A and Canal Point when Lake Okeechobee is low (generally below 11.0 feet). Such occasions are very rare but could occur in the late spring.
- 3) To make regulatory discharges from Lake Okeechobee when conditions in the EAA will permit.

Flood Discharge Characteristics

Design Standard Project Flood

Discharge Rate: 900 cfs 1250 cfs

Headwater Elevation: 10.5 feet 24.8 feet

Tailwater Elevation: 10.0 feet 13.5

Maximum Hurricane Tide Elevation: 31.5 feet

Wave run-up (above hurricane tide): 7.8 feet

Water Level which will by-pass structure: 38 feet

Hydraulic and Hydrologic Measurements

Water Level: On-site, upstream and downstream analog recorders and downstream remote digital recorder

Gate Position Recorder: On-site analog recorders

Rain Gauge: On-site analog recorder

Discharge: U.S.G.S. flow instruments in West Palm Beach Canal

S-3 (S-354)

This structure is a reinforced concrete, gated spillway, with two vertical lift gates, located in L-D9, the perimeter dike of Lake Okeechobee, at the north end of the Miami Canal at Lake Harbor. It is a replacement for Hurricane Gate Structure (HGS)-3.

Access

Structure located adjacent to U.S. 80 at Lake Harbor.

Purpose

This structure permits releases to be made from Lake Okeechobee to meet water requirements in the Miami Canal service area to the Lower East Area and to the Everglades National Park. It will permit flood flows to be discharged from the Agricultural Area into Lake Okeechobee when the lake level is low. It will also prevent hurricane tides from entering the Miami Canal. It will be used, under certain conditions, to make regulatory or water supply releases from Lake Okeechobee into Water Conservation Area 3 or the Holey Land.

Operational Criteria

The gates are normally closed. They are opened for four purposes:

- 1) To meet agricultural requirements in the area served by the Miami Canal between Lake Harbor and S-8, or to meet requirements in Coastal Dade County or in the Everglades National Park. These conditions generally occur in the dry season between mid-October and mid-May. The first condition occurs under a dry season stage below 11.0 feet between S-354 and S-8, along with other factors. The second condition occurs under a dry season stage below optimum in Coastal Dade County when water is not available in Water Conservation Area 3. The third requirement occurs under a condition when the legally required releases to the Everglades National Park cannot be met by releases from Water Conservation Area 3.
- 2) To discharge flood flows from the Agricultural Area between S-354 and S-8 when Lake Okeechobee is low (generally below 11.0 feet). Such occasions are very rare but could occur in the late spring.
- 3) To make regulatory discharges from Lake Okeechobee when conditions in the EAA will permit, and when WCA-3 is below schedule.
- 4) To release water from Lake Okeechobee into the Holey Land as required.

Flood Discharge Characteristics

Design Standard Project Flood

Discharge Rate: 1450 cfs 2000 cfs

Headwater Elevation: 10.5 feet 24.8 feet

Tailwater Elevation: 10.0 feet 13.2

Maximum Hurricane Tide Elevation: 33.6 feet

Wave run-up (above hurricane tide): 7.4 feet

Water Level which will by-pass structure: 34.0 feet

Hydraulic and Hydrologic Measurements

Water Level: On-site, upstream and downstream analog recorders and remote digital recorders at S-3

Gate Position Recorder: On-site analog recorders

Rain Gauge: On-site analog at S-3

Discharge: U.S.G.S. flow instruments in Miami Canal

S-4

This structure is a three unit pumping station located in the alignment of Lake Okeechobee South Shore Levee at the intersection of L-D1 and C-20 in Glades County about 3 miles northwest of Clewiston, Florida. The pumping station is equipped with three Fairbanks Morse 132 inch diameter vertical axial flow pumps, each rated for 935 cfs. at 7.0 foot static head. Each pump unit is driven by a Fairbanks Morse Model 38D8 -1/8, 1600 Horsepower diesel engine.

Purpose

The purpose of the structure is to pump surplus water into Lake Okeechobee via the L-D1, C-20, C-21 and Industrial Canals from the agricultural area generally south of the structure. This surplus consists of seepage through the Herbert Hoover Dike and runoff at the rate of 3/4 inch per day from the 112 sq. mile tributary drainage area, and at the rate of 2.5 inches per day from the 4.3 sq. mile urban drainage area of the city of Clewiston.

Operation

Two types of operation will prevail - normal operation and hurricane operation. The latter will take precedence if, and only if, a hurricane alert is declared. The operation of S-4 is related to the operation of the various features in the S-4 basin, which is summarized in the following table:

Lake Okeechobee	Gate Status				Normal Range HW
	S-310	L-D-1 Culverts	S-235	S-169	
Over 15.5	Closed	Closed	Full Open	Auto	11-14
14-15.5	Full Open	Closed	Full Open	Closed	11-14
13-14	Full Open	Closed	Full Open	Closed	11-14
Below 13	Full Open	Full Open	Closed	Full Open	Below 13

Regardless of the
of these

status or stages at any
structures, however,

pumping at S-4 is initiated only when its headwater stage reaches 14.0. At any time of the year and at any Lake stage, the hurricane operation will

be as follows: *When a hurricane alert is proclaimed, S-235, S-310 and the drainage culverts through L-D1 will be fully closed, pumping will be initiated at S-4, and the headwater stage brought down to and maintained at elevation 10.0.*

The Operation Chart defines the entire recommended range over which pumping can be accomplished. Inasmuch as the reduction ratio between engine and pump is fixed, all pump rotative speeds are expressed in the engine speed which is indicated on the engine tachometer. The rated speed is 755 rpm. At this speed, each pump will discharge 935 cfs or greater with pool to pool heads not in excess of 7.0 feet and intake pool stage between elevation 13 and 9.5. Should pumping be required at pool to pool heads between 7.0 and 10.0 feet, such pumping may be accomplished at the rated speed and a resultant reduced flow, provided that at higher heads the engine temperatures do not exceed permissible maximums.

Flood Discharge Characteristics

Discharge rate: 2805 cfs

Headwater Elevation: 13.0 feet

Tailwater Elevation: 19.2 feet

Hydraulic and Hydrologic Measurements

Water Level On-site, staff gauge and remote upstream and downstream digital recorder

Gate Position Recorder: None

Date of Transfer: July 11, 1975

S-65E

This structure is a reinforced concrete, gated spillway with discharge controlled by six cable operated vertical lift gates and a reinforced concrete lock structure with two pairs of sector gates. Operation of the spillway gates is manually controlled. The structure is located on Canal 38 about 7.3 miles downstream from S-65D and 49 miles downstream from Lake Kissimmee.

Access

From State Road #70 via about one mile of access road.

Purpose

This structure maintains optimum upstream water control stages in Canal 38, the Kissimmee River; it passes the design flood (30% of the Standard Project Flood) without exceeding the upstream flood design stage and restricts downstream flood stages and channel velocities to the non-damaging levels of the design flood, even if the inflow exceeds that flood; and it passes sufficient discharge during low-flow periods to maintain downstream stages and irrigation demands.

Spillway Operation: This structure will be operated, subject to hydraulic and structural restraint, to maintain an optimum headwater elevation of 21.0, insofar as possible.

Structure Limitations: The maximum water level drop across the structure will be 10.5 feet.

Hydraulic Limitations: To prevent damage from high velocity discharge, the gate opening will be limited in accordance with the "Maximum Allowable Gate Opening Curve".

Flood Discharge Characteristics

Design Standard Project Flood:

Discharge Rate: 24,000 cfs 26,000* cfs

30 % SPF 100 % SPF

Headwater Elevation: 22.0 feet 24.2 feet

Tailwater Elevation: 19.2 feet 19.0 feet

uncontrolled controlled*

Type Discharge: submerged submerged

Water Level which will by-pass structure: 32.5 feet

** Type and rate of discharge with no limitation on gate opening. Gate opening limitation will restrict discharge rate to 19,000 cfs. If gates opened sufficiently for uncontrolled flow, discharge would exceed 30,000 cfs.*

Hydraulic and Hydrologic Measurements

Water Level On-site dual recorder

Gate Position Recorder On-site

Date of Transfer: October 16, 1967

S-71

The structure is located on Canal 41 about 2 miles upstream from Lake Okeechobee. This structure is a reinforced concrete, gated spillway with discharge controlled by three stem operated, vertical lift gates. Operation of the gates is automatically controlled in accordance with the established operational criteria.

Access

Structure located on State Road 721.

Purpose

This structure maintains optimum upstream water control stages in Canal 41; it passes the design flood (30% of the Standard Project Flood) without exceeding the upstream flood design stage and restricts downstream flood stages and channel velocities to non-damaging levels; and it prevents backflow from Lake Okeechobee during excessive stages in the lake caused by floods or wind tides.

Operational Criteria

This structure will be operated to maintain an optimum headwater elevation between 19.8 and 20.2, insofar as possible, through automatic controls as follows:

When the headwater elevation rises to 20.2, the gates will open at six inches per minute;

When the headwater elevation rises or falls to 20.0, the gates will become stationary;

When the headwater elevation falls to 19.8, the gates will close at six inches per minute.

When the tailwater rises to within 0.2 feet of the headwater, the gates close to prevent backflow through the structure.

Flood Discharge Characteristics

Design* Standard Project Flood**

Discharge Rate: 6000 cfs 6800 cfs

30 % SPF 100 % SPF

Headwater Elevation: 20.0 feet 22.2 feet

Tailwater Elevation: 19.0 feet 19.0 feet

uncontrolled uncontrolled

Type Discharge: submerged submerged

* Design discharge apparently cannot be obtained with given headwater and tailwater elevation even with uncontrolled discharge. No curve available for uncontrolled discharge, so headwater elevation for design flow unobtainable.

** For Standard Project Flood, headwater and tailwater elevations and maximum gate opening limit discharge to 4300.

Hydraulic and Hydrologic Measurements

Water Level Easy Logger Remote Digital Recorders

Gate Position Recorder Easy Logger Remote Digital Recorder

Date of Transfer: February 13, 1961 (beneficial occupancy); December 27, 1961

S-72

The structure is located on Canal 40 about 4 miles upstream from Lake Okeechobee. This structure is a reinforced concrete, gated spillway with discharge controlled by two stem operated, vertical lift gates. Operation of the gates is automatically controlled in accordance with the established operational criteria.

Access

From State Road 78 via access road on west bank of C-40.

Purpose

This structure maintains optimum upstream water control stages in Canal 40; it passes the design flood (30% of the Standard Project Flood) without exceeding the upstream flood design stage and restricts downstream flood stages and channel velocities to non-damaging levels; and it prevents backflow from Lake Okeechobee during excessive stages in the lake caused by floods or wind tides.

Operational Characteristics

This structure will be operated, subject to hydraulic and structural restraint, to maintain an optimum headwater elevation between 20.2 and 21.2, insofar as possible, through automatic controls as follows:

- When the headwater elevation rises to 21.2, the gates will open at six inches per minute;
- When the headwater elevation rises or falls to 20.7, the gates will become stationary;
- When the headwater elevation falls to 20.2, the gates will close at six inches per minute.
- When the tailwater rises to within 0.2 feet of the headwater, the gates close to prevent backflow through the structure.

Flood Discharge Characteristics

Design* Standard Project Flood**

Discharge Rate 3120 cfs 3800 cfs

30 % SPF 100 % SPF

Headwater Elevation 20.4 feet 23.5 feet

Tailwater Elevation 19.9 feet 19.9 feet

uncontrolled uncontrolled

Type Discharge submerged submerged

* Design discharge apparently not obtainable with given headwater and tailwater elevations, even with uncontrolled discharge.

** For Standard Project Flood discharge, headwater and tailwater elevation, gates have to be opened more than allowable. If gates limited to allowable opening, discharge would be 2000 cfs, given headwater and tailwater elevations.

Hydraulic and Hydrologic Measurements

Water Level Easy Logger Remote Digital Recorders

Gate Position Recorder Easy Logger Remote Digital Recorder

S-77

The structure is located on Canal 43 (the Caloosahatchee River) at the outlet of Lake Okeechobee. This structure is a reinforced concrete, gated spillway with discharge controlled by four cable operated, vertical lift gates. Operation of the gates is manually controlled.

Access

From U.S. 27 via access road on east side of C-43.

Purpose

The structure provides control of regulatory discharge from Lake Okeechobee to the Caloosahatchee River; it passes the design flood (30% of the Standard Project Flood) without exceeding the upstream flood design stage and restricts downstream flood stages and channel velocities to the non-damaging levels of the design flood; and it passes sufficient discharge during low-flow periods to maintain downstream stages and irrigation demands.

Operational Criteria

This structure is operated and maintained by the Corps of Engineers, subject to hydraulic and structure restraint, to maintain the required stage in Lake Okeechobee and to meet downstream water requirements.

The operation can be divided into two modes, low-water operation and flood operation as follows:

Low-water Operation:

Releases will be made as required to maintain a tailwater elevation of 11.1 feet.

Flood Operation:

Flood releases will be made to maintain the Lake Okeechobee operation schedule. These releases will be determined by the U.S. Corps of Engineers.

Hydraulic Limitations:

To prevent damage from high velocity discharge, the gate opening will be limited in accordance with the "Maximum Allowable Gate Openings" curve. Gate settings should be checked frequently to ensure that the design capacity of the structure is not being exceeded.

Flood Discharge Characteristics

Design Standard Project Flood:

Discharge Rate 9300 cfs 9300 cfs

30 % SPF 100 % SPF

Headwater Elevation: 16.4 feet 23.5 feet

Tailwater Elevation: 13.1 feet 13.1 feet controlled

Type Discharge: submerged submerged

NOTE: This SPF is not simultaneous with the SPF at S-78.

Hydraulic and Hydrologic Measurements

Water Level On-site, upstream and downstream recorders

Gate Position Recorder: none

S-84

The structure is located on Canal 41A about 12 miles downstream from S-83 and about a mile upstream from the junction of C-41A with C-38, the Kissimmee River. This structure is a reinforced concrete, gated spillway with discharge controlled by two cable operated, vertical lift gates. Operation of the gates is automatically controlled in accordance with the established operational criteria.

Access

From State Road 70 via access road on south side of C-41A.

Purpose

This structure maintains optimum upstream water control stages in Canal 41A; it passes the design flood (30% of the Standard Project Flood) without exceeding the upstream flood design stage and restricts downstream flood stages and channel velocities to non-damaging levels; and it prevents backflow from Lake Okeechobee through C-38 during excessive stages in the lake resulting from floods or wind tides.

Operational Criteria

This structure will be operated to maintain an optimum headwater elevation between 24.3 and 25.2, insofar as possible, through automatic controls as follows:

- When the headwater elevation rises to 25.2, the gates will open at two feet per hour;
- When the headwater elevation rises or falls to 24.7, the gates will become stationary;
- When the headwater elevation falls to 24.3, the gate will close at three inches per minute.

There is a time delay in automatic gate control. The stage may drop quite lower than the closing level before the gates are closed.

Flood Discharge Characteristics

Design* Standard Project Flood

Discharge Rate: 5680 cfs 9000 cfs

30 % SPF 100 % SPF

Headwater Elevation: 24.5 feet 32.8 feet

Tailwater Elevation: 19.3 feet 24.1 feet

Type Discharge

* To obtain required discharge with given headwater and tailwater elevations, gates must be opened wider than allowable.

Hydraulic and Hydrologic Measurements

Water Level On-site, upstream recorder

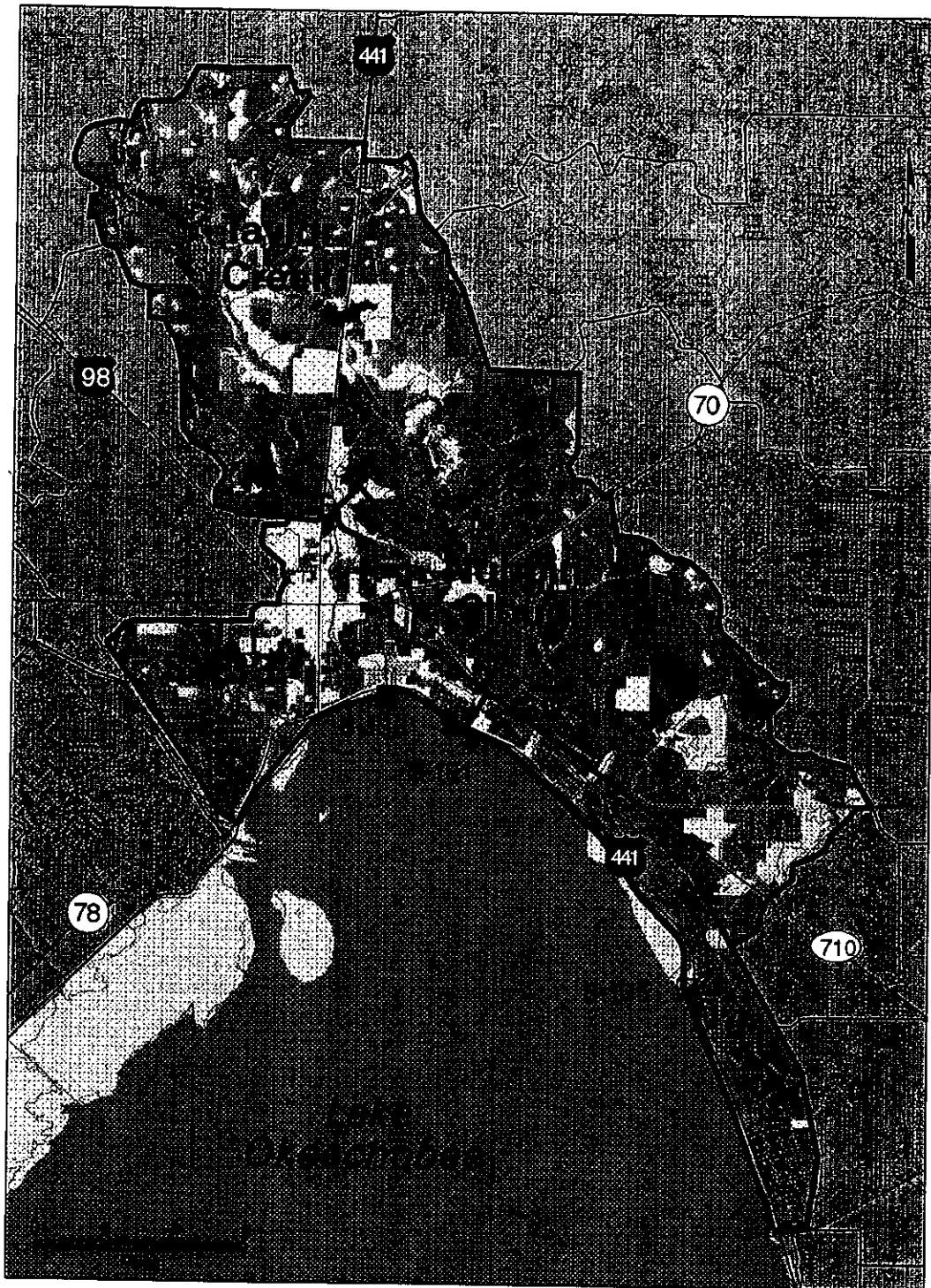
Gate Position Recorder: On-site

Date of Transfer: December 8, 1961 (beneficial occupancy); March 25, 1963








APPENDIX B

**Level One Landuse for the Source Drainage Basins of all Lake Okeechobee
Inflow/Outflow Monitoring Program (X Project) Sampling Stations.
(Figures 1-9)**







Landuse for the Source Drainage Basins of X Project Sites: S-133, S-191 and S-135



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Color

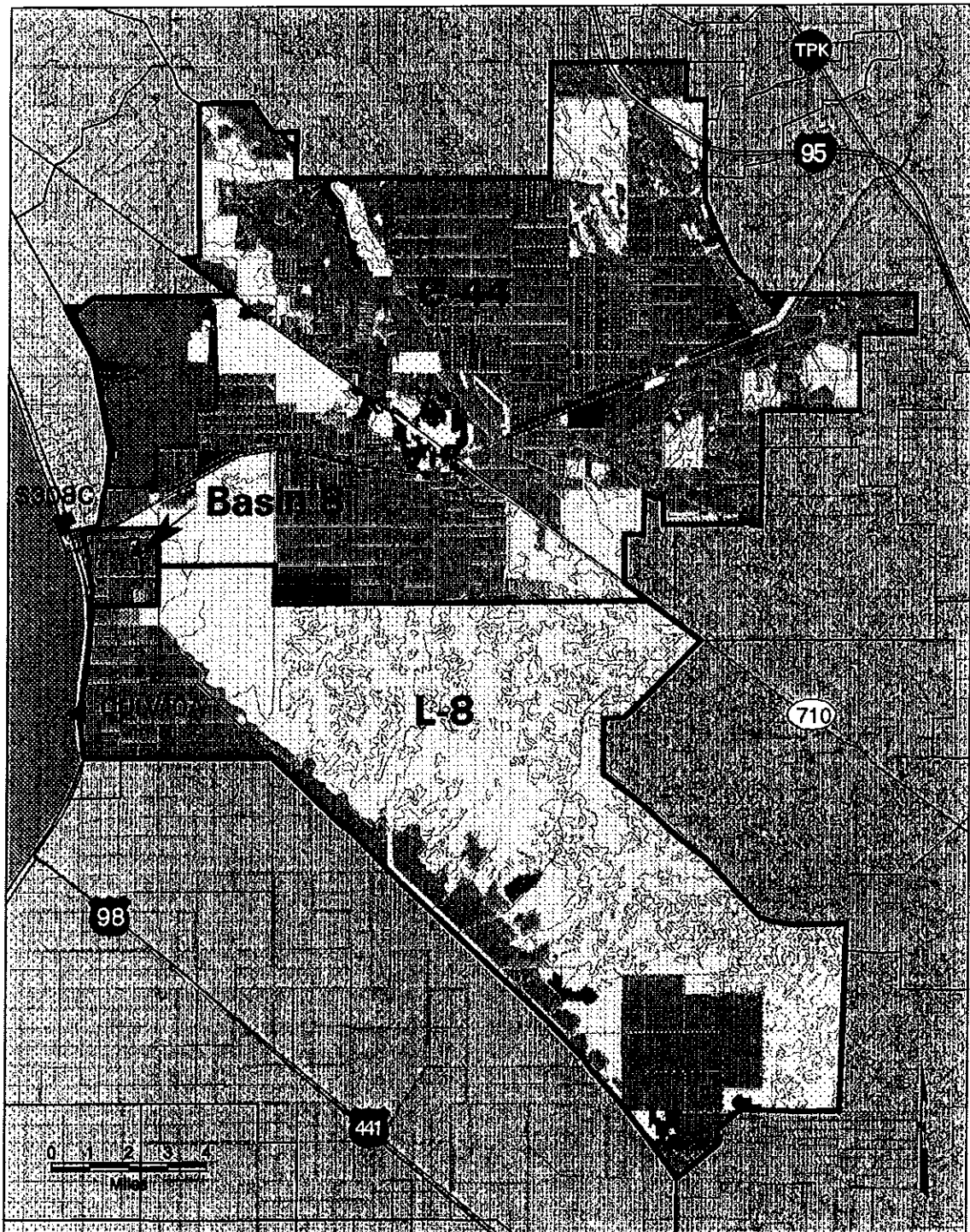
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-  Barren
-  Forested
-  Water
-  Rangeland
-  Urban
-  Wetlands










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-  Spillway & Lock
-  Culvert
-  Pump Station
-  Pump Station & Lock
-  Mid-Canal Station

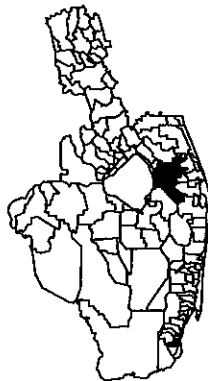
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Landuse for Source Drainage Basins of X Project Sites: S-308C and CULV10A



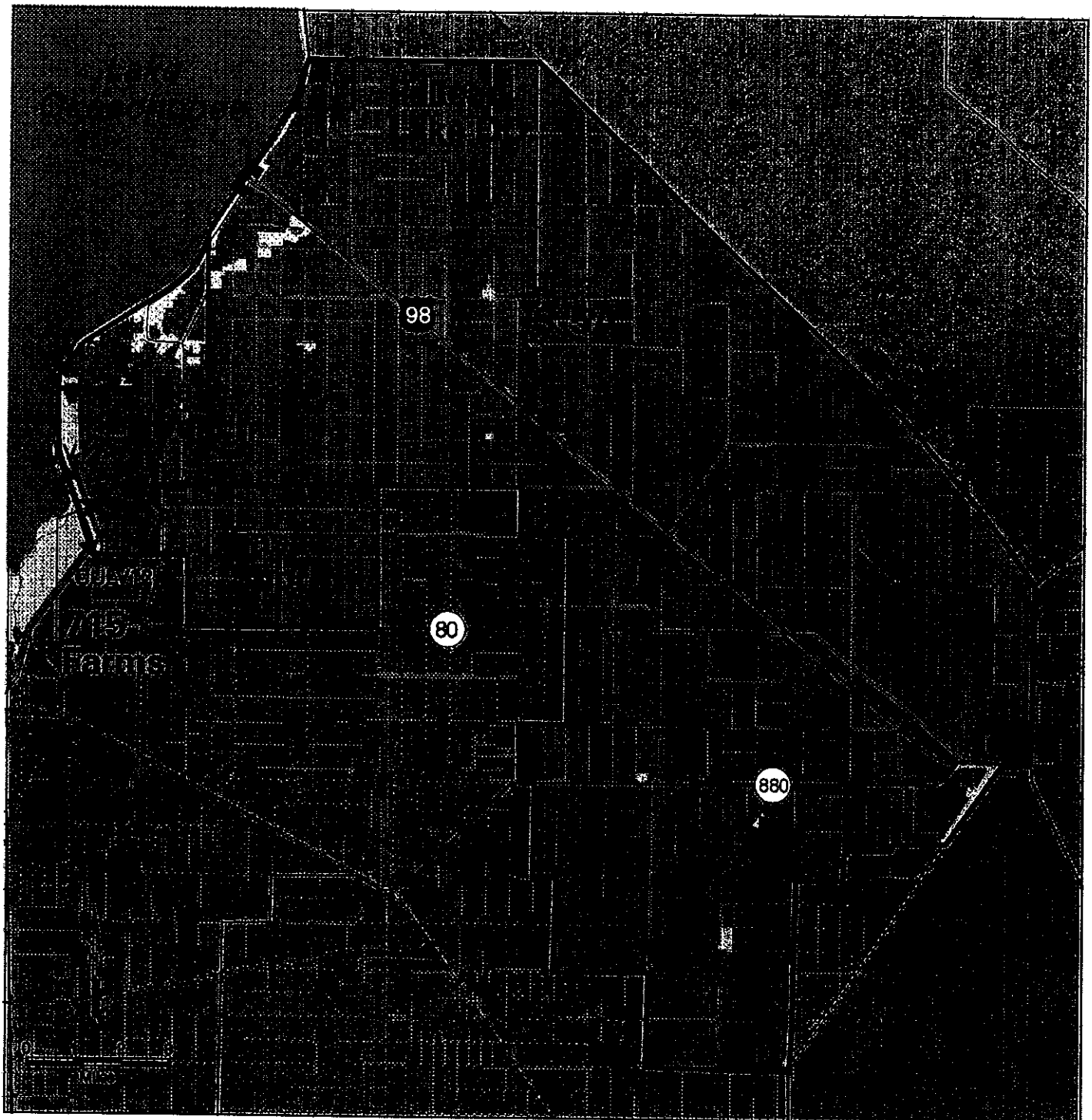
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-  Agriculture
-  Barren
-  Forested
-  Water
-  Rangeland
-  Urban
-  Wetlands

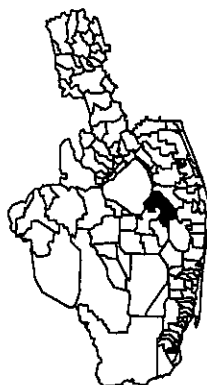








-  Spillway
-  Spillway & Lock
-  Culvert
-  Pump Station
-  Pump Station & Lock
-  Mid-Canal Station

Landuse for the Source Drainage Basins of X Project Sites: S-352, CULV10, CULV12A and CULV12



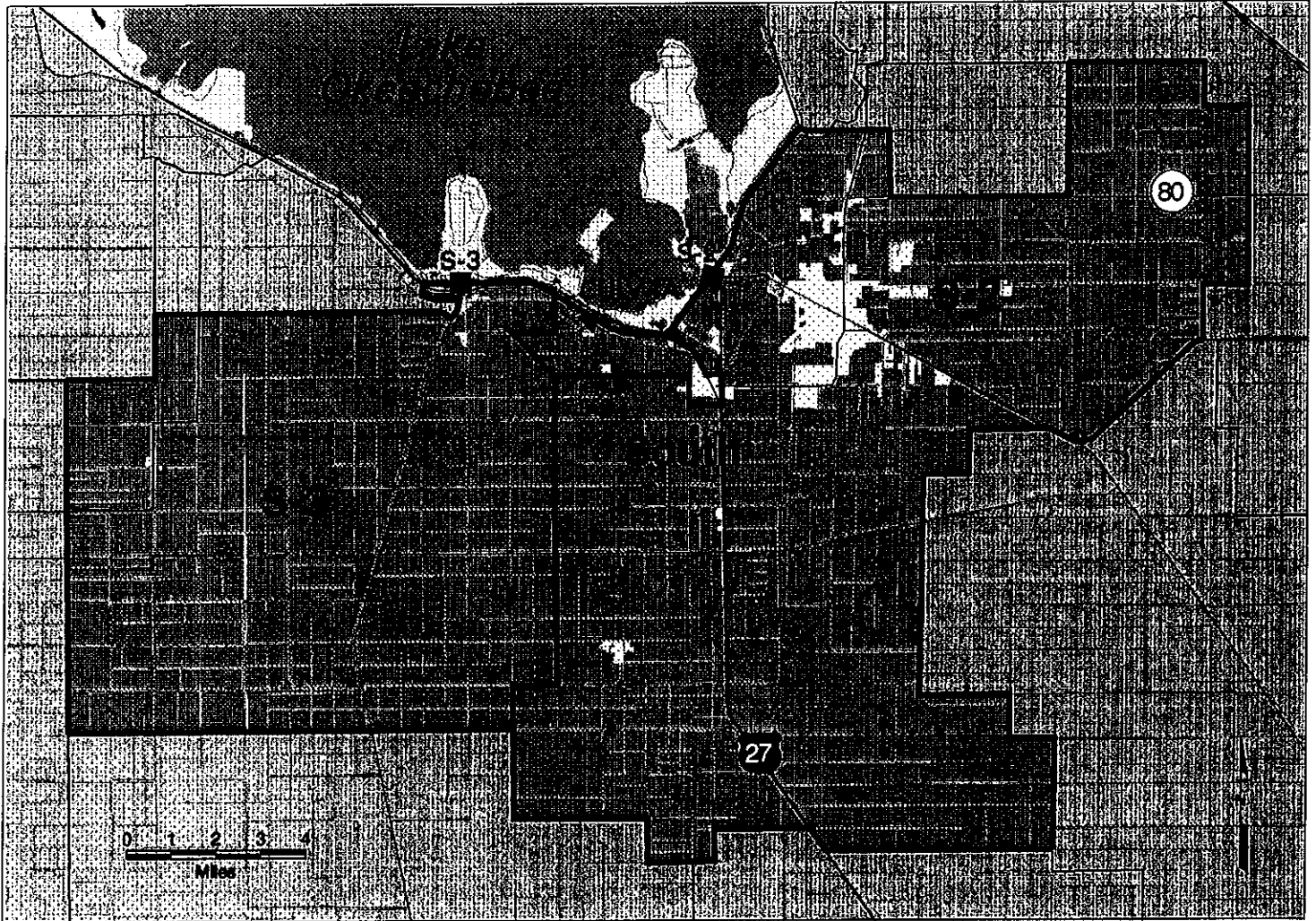
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-  Water
-  Rangeland
-  Urban
-  Wetlands










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-  Spillway & Lock
-  Culvert
-  Pump Station
-  Pump Station & Lock
-  Mid-Canal Station

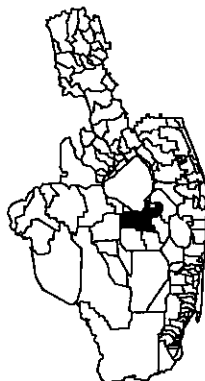
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Landuse for the Source Drainage Basins of X Project Sites: S-2, CULV4A and S-3



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Color

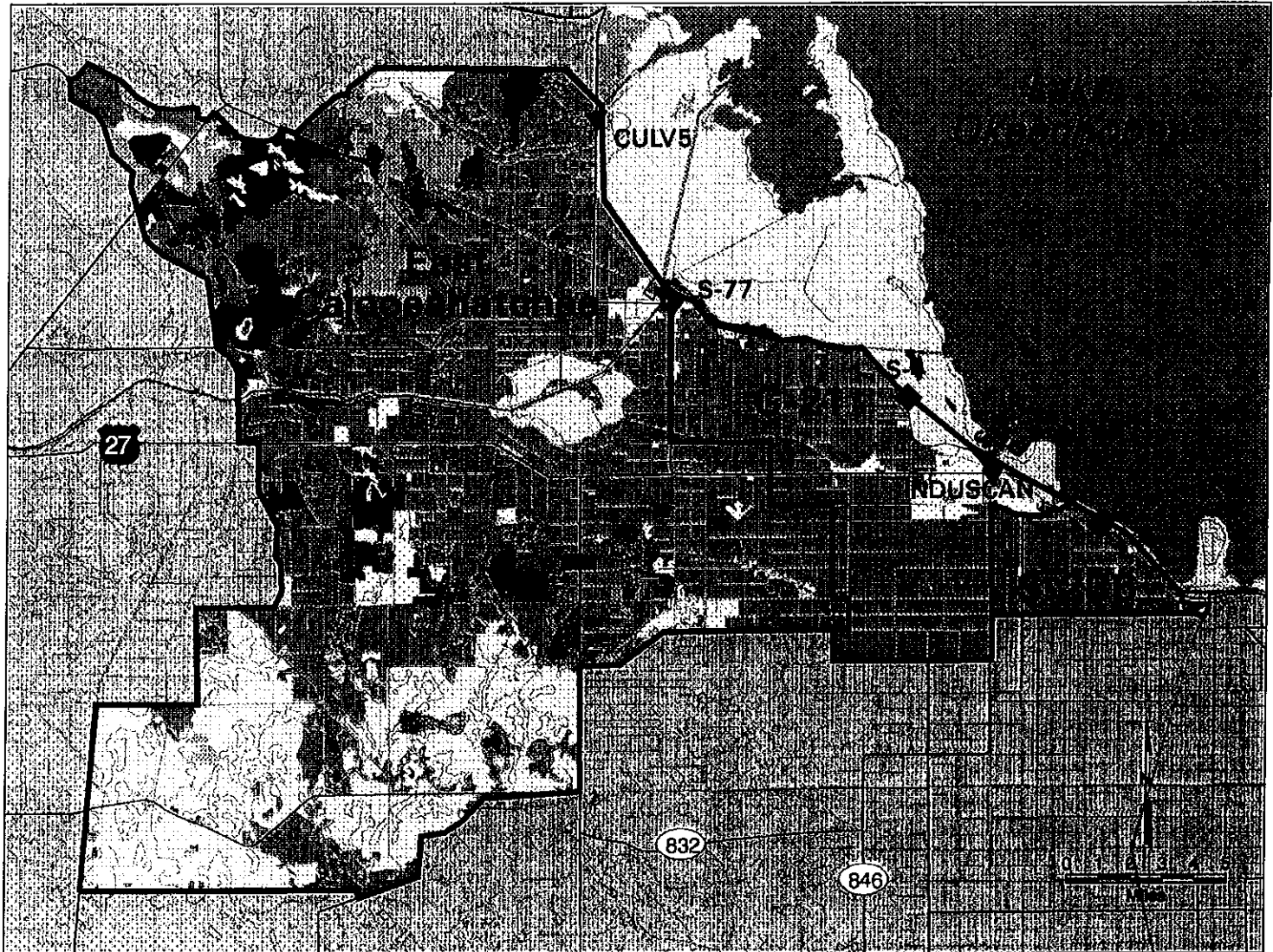
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-  Water
-  Rangeland
-  Urban
-  Wetlands









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-  Spillway & Lock
-  Culvert
-  Pump Station
-  Pump Station & Lock
-  Mid-Canal Station

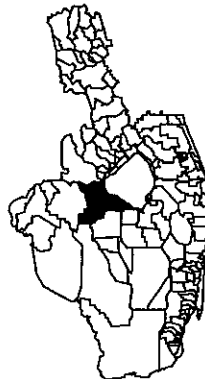
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Landuse for the Source Drainage Basins of X Project Sites: S-236, INDUSCAN, S-169, S-4, S-77 and CULV5



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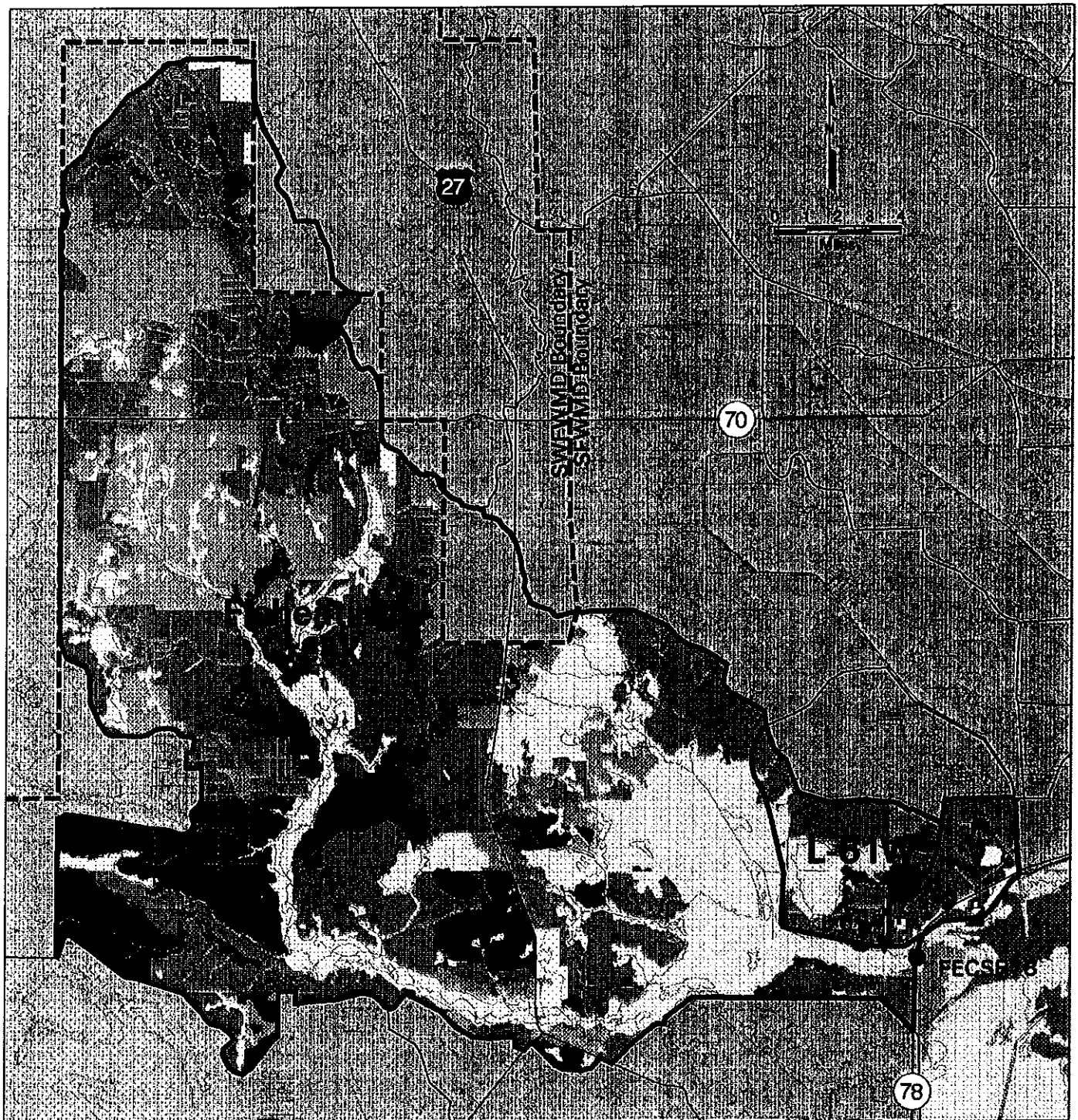
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-  Forested
-  Water
-  Rangeland
-  Urban
-  Wetlands



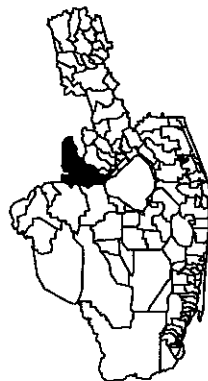
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-  Spillway & Lock
-  Culvert
-  Pump Station
-  Pump Station & Lock
-  Mid-Canal Station

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Landuse for the Source Drainage Basins of X Project Sites: FECSR78, L-61W and S-131



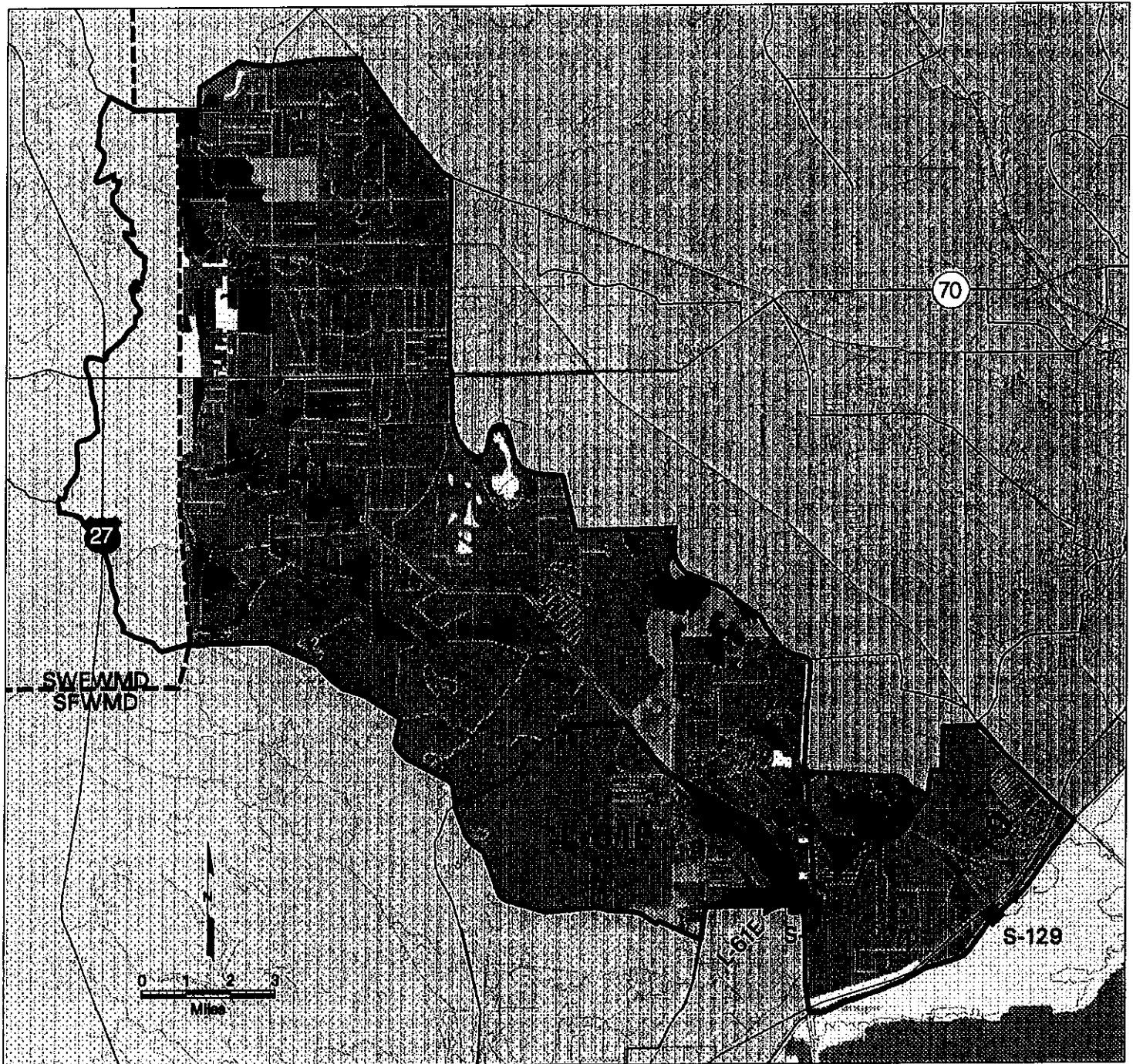
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- Forested
- Water
- Rangeland
- Urban
- Wetlands










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- Spillway & Lock
- Culvert
- Pump Station
- Pump Station & Lock
- Mid-Canal Station

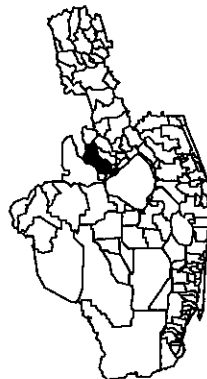
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Landuse for the Source Drainage Basins of X Project Sites: S-71, L-61E, L-60W and S-129



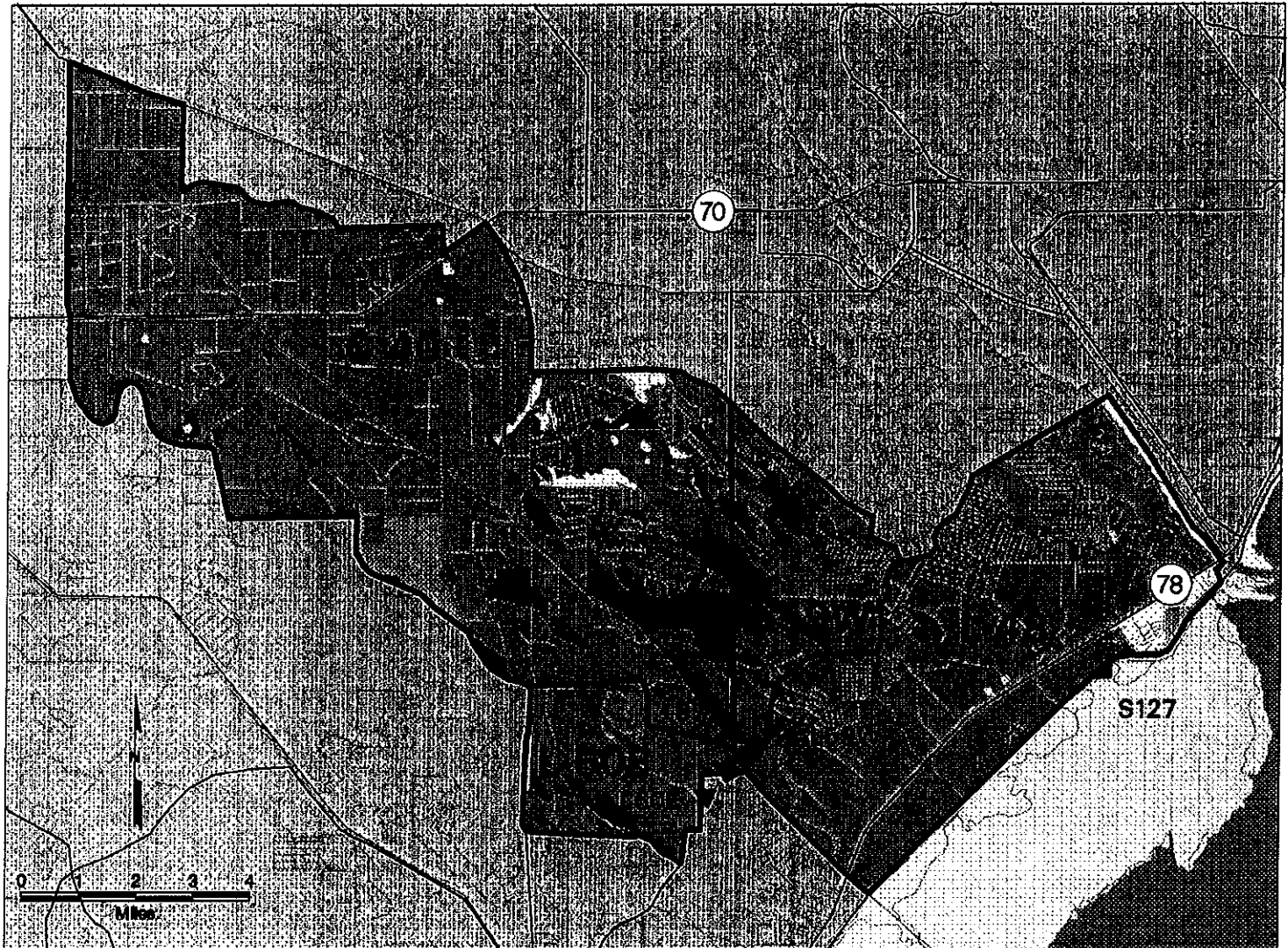
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-  Agriculture
-  Barren
-  Forested
-  Water
-  Rangeland
-  Urban
-  Wetlands










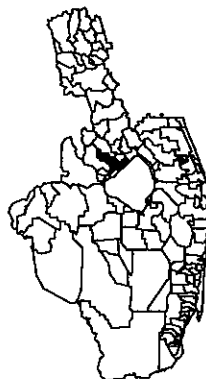
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-  Pump Station
-  Pump Station & Lock
-  Mid-Canal Station







Landuse for the Source Drainage Basins of X Project Sites: S-72, L-60E, L-59W and S-127



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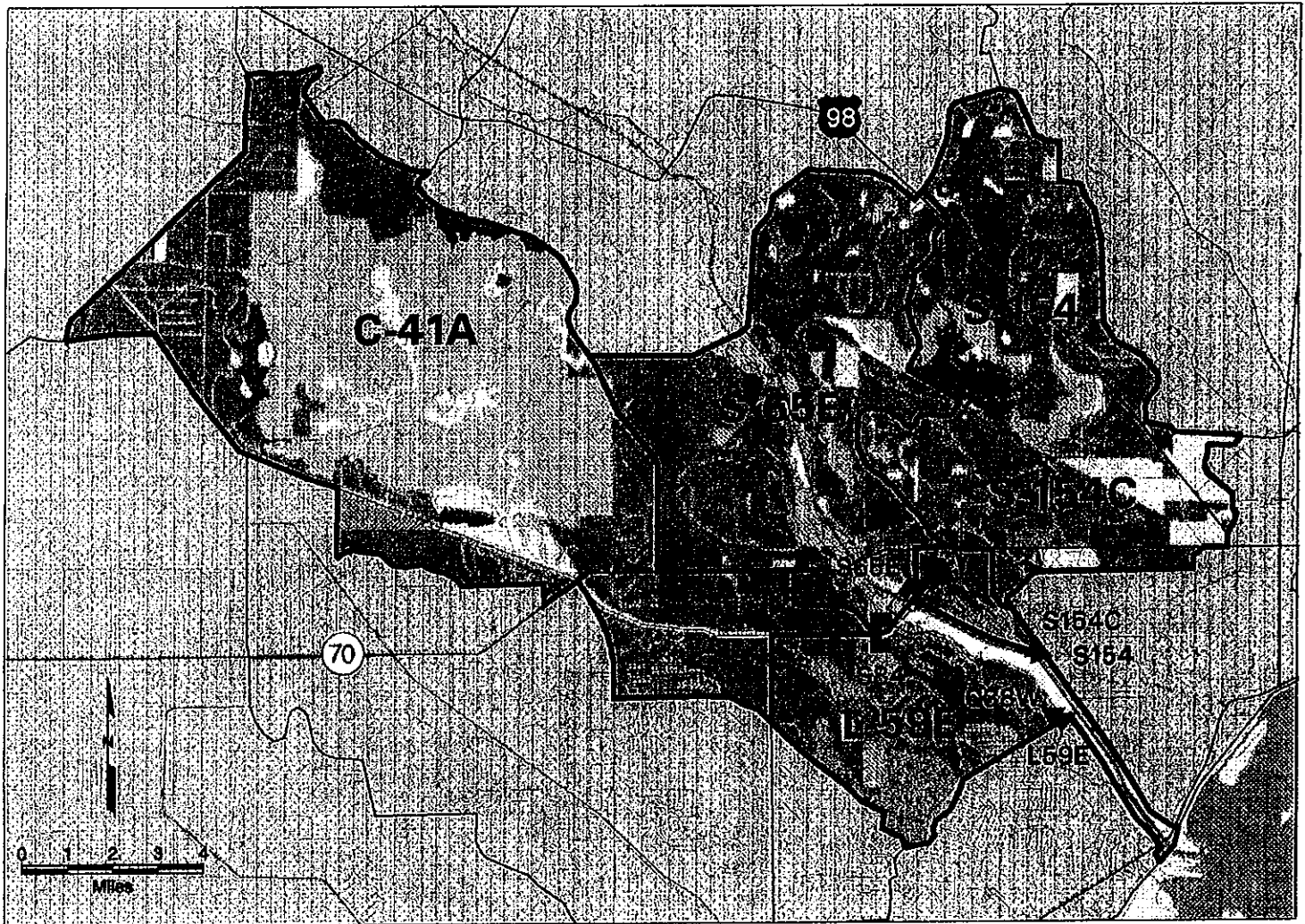
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-  Rangeland
-  Urban
-  Wetlands










-  Spillway
-  Spillway & Lock
-  Culvert
-  Pump Station
-  Pump Station & Lock
-  Mid-Canal Station

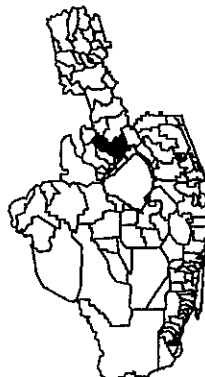
SFWMD 1986-88 LANDUSE







Landuse for the Source Drainage Basins of X Project Sites: S-84, S-65E, S154C, S-154, C-38W and L-59E



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color

-  Agriculture
-  Barren
-  Forested
-  Water
-  Rangeland
-  Urban
-  Wetlands



-  Spillway
-  Spillway & Lock
-  Culvert
-  Pump Station
-  Pump Station & Lock
-  Mid-Canal Station

SFWMD 1986-88 LANDUSE

APPENDIX C

Copy of the X Project Questionnaire and All Corresponding Responses.

To: All Lake Okeechobee Inflow/Outflow Monitoring Program ("X" Project)
Data Users

From: Patricia Burke, Staff Environmental Scientist, Okeechobee Water Quality
Monitoring

Through: Joe Albers, Supervising Professional, WQM and Maxine Cheesman, Division
Director, WQM

Date: 12 March 1996

Subject: "X" Project Issues Questionnaire

The SFWMD is at a pivotal stage in many of the major research projects and legal objectives concerning and affecting the Lake Okeechobee watershed. These include the Kissimmee River Restoration Project and the development of the new Lake Okeechobee SWIM Plan. We are also in the application stage for renewal of the Lake Okeechobee Operating Permit (LOOP), issued by FDEP. It would seem prudent to take the time, **now**, to ensure the functionality of one of the main monitoring projects supplying data crucial to these directives.

The Lake Okeechobee Inflow/Outflow Monitoring Program ("X" Project) is utilized by several District departments as well as outside agencies to fulfill the need of maintaining the water resources of South Florida. The following questions were developed in an effort to clearly identify all the information needs of this program's data set and to determine any areas where this monitoring program is in need of improvement. Some questions may not be applicable to the way you utilize this data set. If this should occur, please write N/A in the answer space provided.

A main objective in evaluating the "X" Project is to project future demands and roles of this data so that it can retain its effectiveness without major overhauls. Please try to get into a "big picture" mode while answering these questions and realize the importance of this data set to system analyses and management (ie. How is LOK water quality data used in management decisions for the Kissimmee River Restoration Program, the Everglades, etc.?).

Your feedback is very important in realizing an optimal project design and any additional comments or questions that you could furnish would also be a tremendous asset.

Name:

Title:

Division/Department/Agency:

1. List all the project names or directives for which you currently or will in the future be utilizing this data set (Please be as specific as possible and include the ultimate goals of these projects if they are not obvious)

- I will be looking at the data to keep up with the TP04 concentrations from the SWIM priority basins. This is not for a specific project (as of yet) but more for personal use when the public asks questions about WQ from the various areas around the lake.

**- LO SWIM Update;
LOOP; and
Class I/III water quality standards for the LOOP**

**- a. Lake Okeechobee Works of the District and SWIM;
b. Under the not so obvious - some Field Eng. Reg. work. Any future local sub- basin storm-water master planning and subsequent implementation could result in STA's or the like being built within the "X" project watersheds. STA's probably would improve the discharge water quality from these major watersheds. A long standing uninterrupted data base would assure an adequate evaluation of potential impacts resulting from such changes in land use.**

**- Lake Okeechobee water quality modeling;
Lake Okeechobee status and trends; and
Lake Okeechobee nutrient budgets**

- Kissimmee River Restoration Program--ecological evaluation: Purpose is to evaluate the restoration project's success in restoring the ecological integrity of the Kissimmee River ecosystem.

- Lake Okeechobee Nutrient and Hydrologic Budgets -- an ongoing project wherein trends in external nutrient loads and water inputs are evaluated using nonparametric statistics. The data also are used to determine nutrient budget parameters, including sedimentation rates.

- 1) Phosphorus Dynamics Study--evaluate use of phosphorus by different biotic compartments in the lake. Competition for phosphorus between planktonic and benthic organisms may influence algal bloom formation in LO. The strength of this competitive interaction will vary depending on the ambient phosphorus concentration in the water, and thus will vary spatially throughout the lake. It is critical to know P levels throughout the lake;

2) Mapping of benthic vegetation--benthic plants are important in sequestering nutrients and stabilizing sediments. Their distribution is influenced, at least in part, by water quality conditions. Knowledge of nutrient budgets into the lake provides important ancillary information.

3) Water quality in the estuaries is influenced tremendously by outflows through S-77 and S-308. These outflows influence estuarine biotic health, and are used in hydrodynamic salinity models.

2. The following tables list all of the parameters currently collected on a biweekly or quarterly basis and all sampling stations monitored on a biweekly, biweekly on flow or monthly basis. Please mark the water quality variables and sites for which you currently or will in the future retrieve data (mark any projected usages with an asterisk):

BIWEEKLY				QUARTERLY			
TURB	COLOR	NOX	PH	TDS	TOTCD	TOTZN	NA
TSS	OPO4	NH4	COND	SO4	TOTCU	TOTHG	K
TKN	NO2	ALKA	DO	SIO2	TOTFE	CA	
TPO4	CL	TEMP		TOTAS	TOTPB	MG	

S133	S352	CULV4A	S4	S131	L60E	C38W
S191	CULV10	S3	S77	L61E	S72	S154
S135	CULV12A	S236	CULV5	S71	L59W	S154C
S308C	CULV12	INDUSCAN	FECSR78	L60W	S127	S84
CULV10A	S2	S169	L61W	S129	L59E	

Parameters used:

TPO4

All

TURB, TSS, TKN, TPO4, OPO4, NO2, CL, NH4, NOX, TEMP, PH, COND, DO, TDS, CA

TURB, TSS, TKN, TPO4, COLOR, OPO4, CL, NOX, NH4, ALKA, TEMP, PH, COND, DO, SIO2, CA

Sites Used:

S133, S191, S71, S72, S154, C38W, L59W, S84, FECSR78, L59E

All

Is S-65E still collected under the X project, or is it now only in the V project? This structure is the only one I'm interested in, and I'm interested in all the parameters above except trace metals.

Potentially All

-Do these parameters and sites supply all of your data needs? If not, please discuss how they could be improved:

-Yes

-Yes.. In general, all these data are indicators of the true loading, which would be impossible to measure. So, the best you can do in getting flow-weighted samples from as many of the sights as possible, the better (in my opinion) the interpretability of the data.

-Yes

- I would like calcium on a monthly basis. I need to work up budgets for future modeling and relationships between calcium and phosphorus net settling in the Lake.

-Yes

-Is the monitoring frequency sufficient for all sites and parameters? Please note: Sites S191, S71, S154 and S84 are mandatory sites and are sampled on a biweekly basis, regardless of flow.

-Yes

-Yes. Why are these the only sites that are monitored regardless of flow??

- More event sampling (peak flows or rainfall events) to improve budgets.

-Yes.

-For those of you calculating loads, nutrient budgets or trends:
How could the scheduling of this trip be altered to reduce the error and/or increase the reliability of your statistics?

- We need the loading numbers and the trends are useful. I leave the frequency of collection for statistical resolution to George Shih to figure out.

- Obviously, it is desirable to have the sampling frequency maximized (within the constraints of funding). In addition to the regular scheduled sampling, it also would be good to have collection of nutrient data triggered by high flow events.

3. The following table is a comparison between the site requirements of the FDEP Lake Okeechobee Operating Permit (LOOP), those sites used in the SWIM Plan's areal target loading standard and those recommended by Lettenmaier (1992) for load calculation and trend detection:

SITE	LOOP	LETTENMAIER	SWIM Plan
S133	X	X	X
S191	X	X	X
S135	X	X	X
S308C		X	X
CULV10A			X
S352			X
CULV10			X
CULV12A			X
CULV12			X
S2	X	X	X
CULV4A			X
S3	X	X	X
S236			X
INDUSCAN		X	X
S169		X	
S4	X	X	X
S77		X	X
CULV5			X
FECSR78	X	X	X
S131	X	X	X
L61W			X
L61E			X
L60W			X
S71	X	X	X
S129	X	X	X
L60E			X
L59W			X
S72	X	X	X
S127	X	X	X
L59E			X
C38W			
S154	X	X	X
S154C			X
S84	X	X	X

-Are the sites that "fall out" of the LOOP + Lettenmaier equation being sampled unnecessarily?

- I think my best thoughts on this are: Develop a criterion, say 3000 acre-ft/ year (average annual) to "weed out" those stations that have so little flow.

An additional criteria could be historic loading of P (ie, anything over 0.5 tons of total P) would also be retained.

- I believe that there is a SWIM regulatory program (LO and EAA) implemented in each of these watersheds. If that is the case then monitoring at all the sites are valuable. Especially for phosphorus load and concentration. The regulated public are always interested in the data at the outflows to their respective watersheds.

- Not if trends exist or are expected to exist.

- Not if the basins they represent are required to meet performance criteria (i.e., TP concentrations of 0.18 mg/L or less) according to the Lake Okeechobee SWIM Rule.

- NO - notice that we utilize data from 12 of those sites.

-Would the elimination of these sites from the "X" Project violate any other regulatory requirements or interfere with data acquisition for any District projects or directives?

- Any of the sites used for the formal Vollenweider load calculation (i.e., from Table GOS-1 of the 1989 SWIM Plan), that have a target, need to be retained or some how incorporated into the total load calculation that we are regulated on. If a down stream sampling point picks up a tiny basin, then it would be conceivable to skip the tiny basin in calculating load. On the other hand, basins out of compliance could/should not be dropped, no matter how small.

- Yes, particularly information dissemination to the regulated community.

- Only in defining budgets for short time periods (months).

4. Lake Okeechobee is a Class I in-lake and Class III inflow water body.

These water quality standards are intrinsic to the Operating Permit. A study recently completed by CH2M HILL evaluated compliance with these criteria and identified exceedances for sites sampled under the "X" Project. Our accountability to FDEP is a foremost consideration and concerns regarding the findings of this study will most likely play a role in the finalization of the Operating Permit.

-Can we expect additional parameters and/or the frequency with which current parameters are sampled to increase as a result of this study's findings?

- The minimum number of metal and pesticide samples was described in the CH2M Hill report (20) or so, with no "violations" before DEP would sign-off.

- Don't think so.

-Is it realistic to attempt to develop some type of Class I/III monitoring supplement to the "X" Project? This sampling regime would not only satisfy FDEP requirements, but also allow us to stay within the realm of our sampling capabilities and scheduling.

- Should be done. I'd like to see it.

- It looks like we are already monitoring for all the parameters required to evaluate Class I and Class III water quality standards in the Lake and in our streams. If so why would you want to supplement a program that is already meeting your needs? Is FDEP asking for more parameters?... more frequent sampling? Are we doing more than what is necessary to satisfy FDEP and if so are you suggesting restructuring to reduce the sampling frequency? If the later is the case then what you would need to be sensitive of is how a change in sampling frequency in a long term data base will impact others ability to perform reliable data analyses. This takes us back to the table above. The question of what parameters are important becomes the controlling factor. Maybe, based on the response to the table, you can identify the most important parameters (phosphours and nitrogen probably being at the top of the list) and cut back or eliminate those parameters that are of little or no importance. In rethinking I could probably cut back on the parameters I asterisked in your table. I think it is human nature to ask for more when they could really get by with less.

- Don't think so.

5. Please list or discuss any additional concerns, suggestions or needs that may not have been addressed in this survey:

- Getting the data out of the system in a timely fashion. In particular, the Total P loadings to the lake, by basin, on a quarterly basis, as soon as possible after the quarter is over.

- Certainly Lettenmaier took a very pragmatic look at our monitoring program. You need to determine through your survey and through other sources what the information needs are both internally and externally. Sometimes the purpose to collect data (ie frequency, many parameters) might not seem scientifically practical. However, the data may serve some public needs, satisfy Governing Board questions or any other host of third party requests. With this in mind you may need to step away from the mandatory requirements of collecting data and try to identify all the potential audiences. Of course when you do identify the audiences then you have to pose the question... Are we required to satisfy their needs? In most cases the answer is probably yes.

- From the scientific standpoint you need to be sensitive to the fact that any changes in data collection frequencies and or methods may present statistical problems for someone who is evaluating the data.

- What about auto-sampling frequency and sampling for events. At some level of frequency, this could help to define the budgets for the lake much better.

